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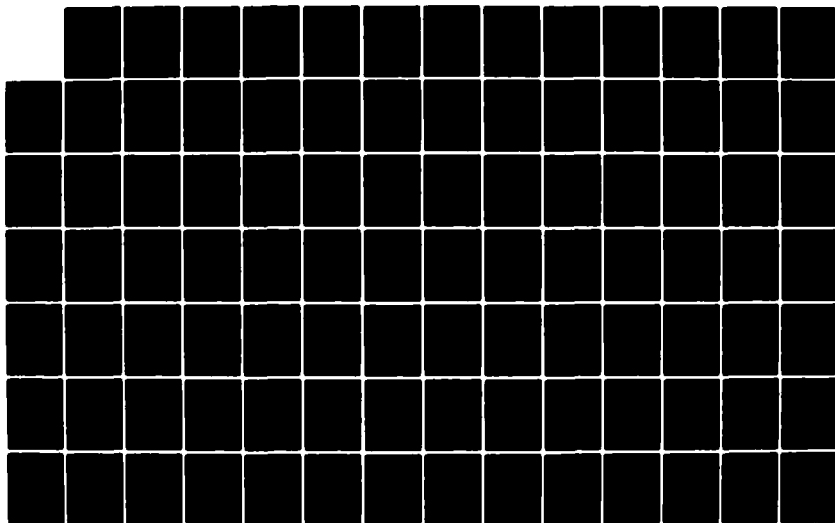
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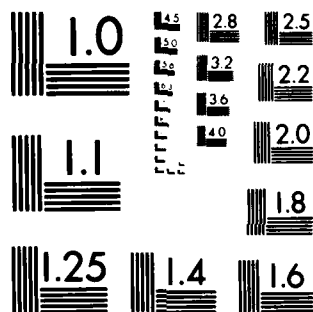
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CONTROL DEVICE MANIPULATIVE BEHAVIOR, AROUSAL  
AND PERFORMANCE DURING A COMPENSATORY TRACKING TASK

BY

HECTOR MICHAEL ACOSTA, B.A.

A Thesis submitted to the Graduate School  
in partial fulfillment of the requirements  
for the Degree  
Master of Arts

Major Subject: Psychology

New Mexico State University  
Las Cruces, New Mexico  
December, 1980

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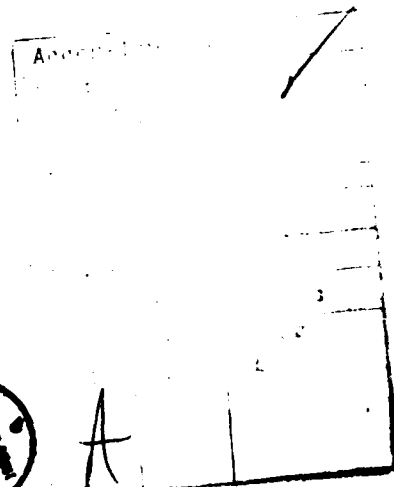
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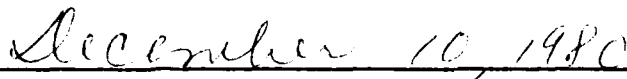
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ABSTRACT

CONTROL DEVICE MANIPULATIVE BEHAVIOR, AROUSAL AND  
PERFORMANCE DURING A COMPENSATORY TRACKING TASK

BY

HECTOR MICHAEL ACOSTA, B.A.

Master of Arts in Psychology

New Mexico State University

Las Cruces, New Mexico, 1980

Dr. Darwin P. Hunt, Chairman

Twelve AFROTC cadet volunteers performed a compensatory tracking task at three levels of difficulty in each of three arousal/activation conditions. The three levels of difficulty were produced by changing the sample/analog-conversion frequency of a digitally stored sinusoidal forcing function. The three arousal conditions included a masking-noise-only (M) situation, a noise (MN) situation and a noise-and-competition (MNC) situation.

Measures of skin resistance and subject self-report indicated that the experimental manipulations of arousal and task difficulty were effective. Improving performance trends across arousal conditions, although

not statistically reliable, were accompanied by an overall reliable decrease in average amplitude of control displacement and a consistent, though not statistically reliable, downward trend for each of two velocity-based control (device) activity measures.

Combined, the obtained results are consistent with a hierarchically based preliminary model which attempts to relate arousal to performance along lines suggested by Fuchs' Progression-Regression Hypothesis (1962). The study failed to generate performance decrements as a function of increasing non-task stimulation (appropriately ordered arousal conditions), and, therefore, could not test major aspects of the proposed model which depend upon interactions between arousal condition and task difficulty. Of primary interest is the apparent high sensitivity of simple control device activity measures to the effects of traditional stress manipulations. Possible implications for system-assisted performance-augmentation during stressful situations and selection/screening applications are discussed.

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## Introduction

Man is often involved in the manual control of complex man-machine systems. Often, these systems must be controlled under other than "nominal" conditions envisioned in their design and development. While the task-related variables involved in system performance may remain stable or, at least, within expected limits, environmental and situational variables, forms of matter, energy, and information which affect the "human component", often come to bear. Such "non-task" variables may alter the human response and thereby affect overall system performance.

During the first quarter of 1980, 19% of all United States Air Force aircraft losses occurred during low-level and similar flying operations; this percentage excludes accidents with known machine system malfunctions or known external environmental influences. The presumed causes have been related to unspecified operator control activity errors somehow related to situational variables. The incidence of low-level operations is, for reasons of tactical and strategic importance, increasing with each passing year. Low-level operations typically involve man-machine interface characteristics which are highly comparable to those of traditional laboratory tracking tasks. In this study, patterns of human response activity at the level of direct man-machine control interface (i.e., joystick manipulative activity in a tracking task) were investigated. Such "graded control activity" responses were proposed to be sensitive to changing non-task conditions and, thereby, to effects of such conditions on performance.

While Adams, in 1961, urged the examination of procedural variables such as motivation, fatigue, and arousal-anxiety in human tracking behavior to augment the then preponderant emphasis on task variables (e.g., nature of the forcing function, the control dynamics, display configurations, etc.) little in the literature reflects such a shift in emphasis. Lazarus et al. (1952), Teichner (1968), Hockey (1970), and Martin (1975) have all urged the examination of behavioral components as they relate to performance in interaction with environmental and emotion provoking conditions. Teichner (1968) and Martin (1975) further caution that unmediated physiological subsystem activity should not be ignored when one is addressing how man, the controller, copes with changes in non-task-specific variables while working in the context of a man-machine system.

If one can identify changes in behavioral patterns which are sensitive to performance changes related to, for example, increases in arousal, one may thereby identify appropriate coping responses to negate potentially detrimental influences on performance. A whole class of man-machine systems involved in situationally critical performance may benefit from such research; such systems include nuclear power plants, numerous military weapon systems, commercial transportation systems, and systems involved in manned-space and undersea exploration.

#### Coping and the Hierarchical Nature of Man

Kelley (1968), Poulton (1972, 1974) and Miller (1978), among others, have argued that man is a complex hierarchical system of

stratified subsystems. Kelley, in discussing man as controller, refers to inner and outer loops of purposive activity; inner loops supporting the outermost loop, the goal or mission of the man-machine system. Such a view is consistent with that of aviation psychologists, Williams (1971) and Roscoe (1980).

Implicit in a description of man as a hierarchical living system is the recognition that man's environment, within the context of a man-machine system, is not limited to those sources of stimulation associated with the "machine." Thus, as an example pertinent to this investigation, a man involved in a tracking task is not only affected by the stimuli coming from the machine system display but potentially also by ambient temperature and noise conditions, anxieties over the potential effect of poor performance, and the ramifications of having eaten too much sauerkraut for lunch earlier in the day. In addition, man's responses are not limited to those consistent with the task; gastric distress over the sauerkraut may definitiely affect perceptual and cognitive processes, which in turn are reflected in inefficiencies in motor-controlling activity.

Teichner (1968), in developing a conceptual approach to the interaction of behavioral and physiological stress, defines a stress reaction as "the variation of an output (of a system) beyond its normal limits" (p. 272) and stressors as "stimuli at intensities or durations which are associated with stress reactions" (p. 272). He further defines two general classes of potential stressors that are exhaustive, but not mutually exclusive. The first class, composed of physical

stimuli, involves some physical forcing function; the second, composed of symbolic stimuli, refers to events with learned and/or genetically derived importance to the organism.

A generalized model of a man-machine system, in this case a compensatory-tracking system, is given in Figure 1. A compensatory task requires the operator to attempt to align a moving index with a fixed command index on a display. The command index may be said to represent the desired state or "goal" of the system and the discrepancy between it and the moving index represents tracking error. The "error" is the summation of the operator's control movement activity as transformed by machine system dynamics, and those aspects of the environment which change relative to machine system activity and must be controlled.

As illustrated, the generalized system depicted in Figure 1 is a closed-loop system which includes as primary components man, the machine, and the environment. Man receives, as inputs, physical and symbolic stimulation from the machine-system display and from the extant physical and psychological environment. Man, in turn, interacts with the machine system through some form of physical activity which, in a tracking task, usually involves the physical displacement of a joystick or some similar device. Man also interacts with his environment at various levels of physical activity including biochemical, electrical, and thermal forms of energy, matter, and information transfer.

The most goal-specific portion of the overall system as depicted is the machine subsystem. While immersed in the environment, some

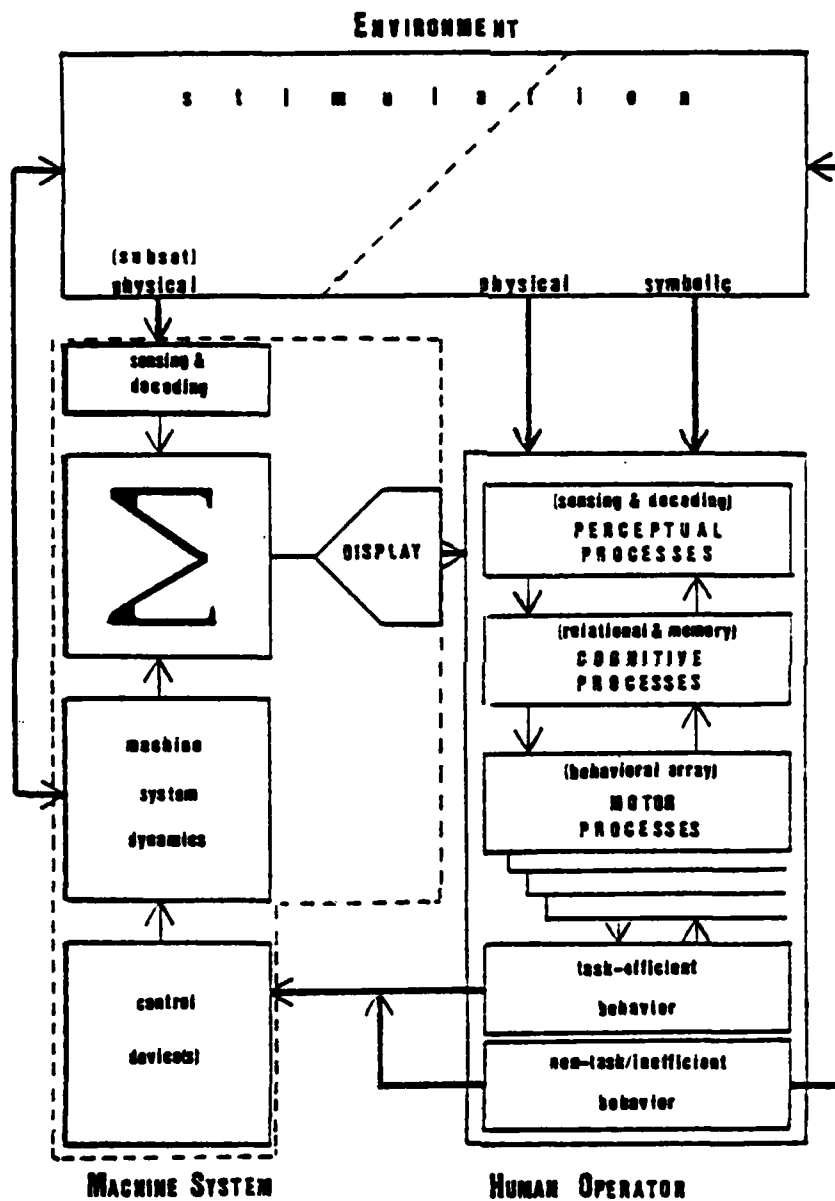


Figure 1. A generalized model of a man-machine-environment system.

aspect or aspects of which it is typically designed to assist man in controlling, the machine "senses" changes in the variable(s) to be controlled, usually in a highly selective fashion. The inputs to the machine system, both selectively sensed and by virtue of man's manipulations, must be transformed for display and direct interaction with the environment, respectively. Outside of the laboratory setting, the summation of the man-machine controlling activity and changes in environmental "controlled variables" occur in the total environmental context to be sensed by the machine system, transformed and displayed to man for loop-closure or feedback.

A significant aspect of the above depiction of a man-machine system is man's capacity to generate both task-efficient and task-inefficient behaviors or varying degrees of efficiency in performance. Welford (1979, Reference Note 2) has described the development of skill in man as the progressive development of more efficient strategies which result in maximization of performance with a concomitant minimization of required energy expenditure. Performance is defined in terms of goal-oriented man-machine system capacity to establish desired states relative to the environment. A logical outgrowth of the concept of "efficient strategy" development is the minimization of irrelevant control activity by man. Since man's behavior is a function of both "machine displayed" and environmentally extant physical and symbolic stimulation, skilled performance involves appropriately and efficiently coping with both.

### A Conceptual Framework

Background. The psychological literature is replete with examples that increases in measured or inferred arousal have resulted differentially in increases, decreases, and no reliable effect on performance (e.g., with auditory noise "stressors": Facilitation--Davies, 1968; Stave, 1977; Watkins, 1964. Hinderance--Broadbent, 1958; Broadbent and Gregory, 1963; Jerison, 1959. No Effect--Hockey, 1970; Wohlwill, et. al., 1976). Where decreases have been noted, the task is typically complex, inferred to reflect an overload of the human operator's capacity or ability to cope. Increments in performance are associated with an approach to some optimal level of arousal for the task.

A post-hoc explanation of the above phenomena, which is recognized by most researchers to be descriptive but not particularly useful, is the inverted-U hypothesis (Yerkes and Dodson, 1908). It proposes a set of relationships between arousal, performance and task complexity as illustrated in Figure 2. As first expounded, Yerkes and Dodson limited the dimension of the independent variable to level of stimulation; subsequent iterations, possibly inappropriately, have expanded this dimension to include "arousal" and, possibly more appropriately, "demand". Two corollaries of the hypothesis often cited (Corcoran, 1965) are first, that increases in task complexity imply shifts to the left of the level of arousal associated with optimum performance and second, that practice toward skill development makes tasks less complex for the practiced man and shifts the optimal level to the right. Two fundamental predictions are therefore explicit in the context of the



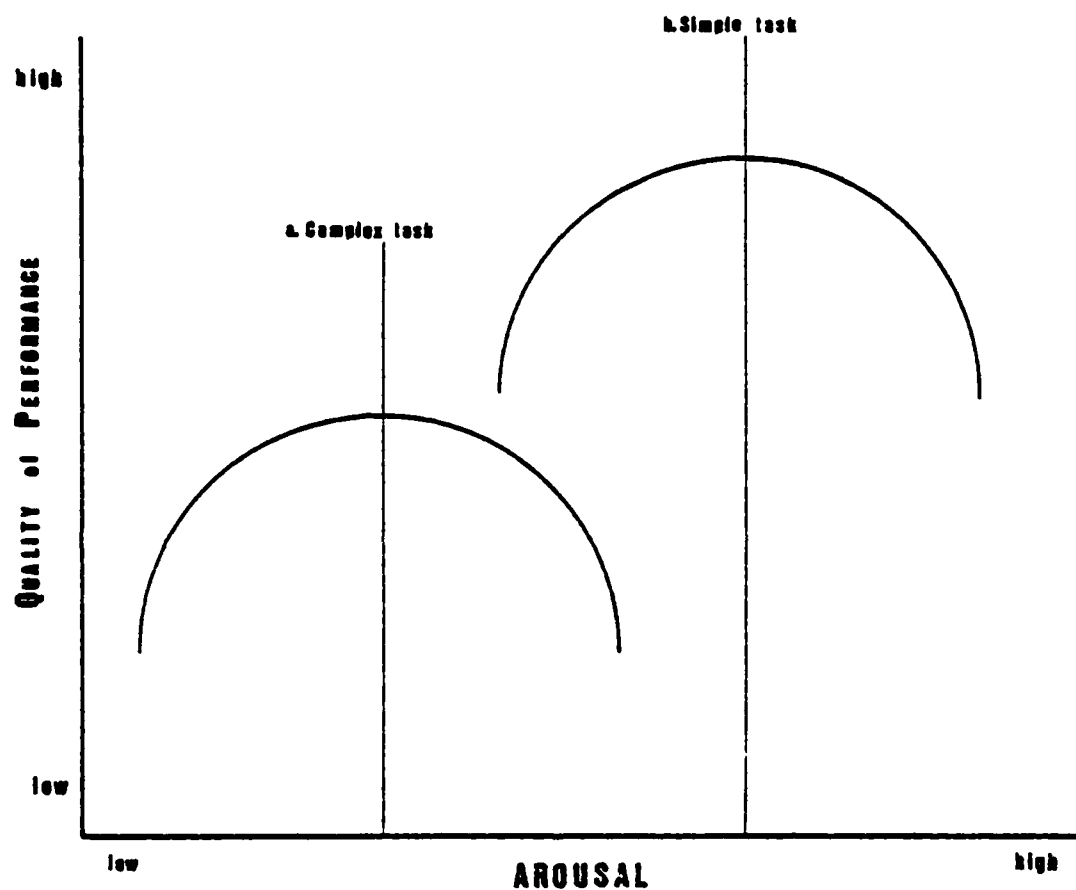


Figure 2. Relationships proposed by the inverted-U hypothesis and corollaries.

inverted-U hypothesis as related to an "arousal" independent variable continuum:

1. Arousal associated with optimal performance in an easy task should be greater than arousal associated with optimal performance in a difficult task.

2. Practice which leads to skill development should increase arousal associated with optimal performance in any given task.

It must be stated that "arousal" as referred to in the above discussion is most often inferred and not measured. Typically, a fixed arousal condition is introduced in an experiment, for example, an increase in auditory noise level. As noise has been demonstrated to increase arousal under certain conditions, the application seems reasonable. The impact of a given noise manipulation on performance seems to support an inverted-U interpretation: incremental performance effects are (when reported) typically associated with simple tasks and decremental effects with complex tasks, given the same noise manipulation.

A difficulty with the above interpretation, however, rests with the implicit assumption that the "level" of arousal produced by a particular "arousal condition" is independent of the difficulty of the task. What is really being manipulated is at best some fixed increment in arousal (level of experimental stimulation) from whatever level exists consistent with a specific level of task complexity. What is proposed as a clarification here is that level of arousal should be considered an interactive and combined function of the specific task complexity and other physical and symbolic environmental stimulation.

Preliminary data with the apparatus designed for this experiment reconfirms the often found greater measured arousal with increased task complexity; average skin resistance measurements were consistently lower when subjects tracked a higher frequency (more difficult) forcing function (FF). The above argues that the effect of task difficulty on measured arousal should be considered in relating arousal and performance.

If traditional measures of arousal, both physiological and self-report checklists, are interpreted to indicate changes in activation (mobilization for energy expenditure mediated by the sympathetic nervous system or perceived activation, respectively), there is no reason to believe that such indices do not reflect, albeit indirectly, an organism's total activity: overt and covert, relevant and irrelevant to the task. In this context, "irrelevant activity" is defined as behavior which does not contribute to the efficient execution of the man-machine system-defined goal. The benchmark for efficiency is the level of activity associated with continued practice once stabilized (optimal) performance has been achieved in training under nominal conditions.

The framework. Hunt (1980, Reference Note 1) has suggested that the concepts of "energy expenditure" and "efficiency", as discussed in general terms by Miller (1978), might be readily applied to the study of continuous control tasks; the following conceptual framework was developed along such lines.

Measured arousal is considered an index of total processing activity within the organism. Total processing activity may be viewed as an index of total energy-expenditure within the organism. "Total energy-expenditure" is meant to imply a collapsed view or composite of energy-expending activity at all hierarchical levels of the organism. These hierarchical levels are assumed to include both purposive, thus selectively applied, sub-processes and automatic, thus mandatory, processes.

Some central processor is assumed to manage the allocation of resources to both purposive and automatic processes. Miller (1978) would assign such activity to a "decider" in his model. If it is assumed that, in the human operator, it is biologically significant to minimize total energy expenditure whenever possible, and, in addition, that there is an upper limit to the rate of energy expenditure in the human organism, simple and empirically supportable principles of energy conservation and limited processing capacity are asserted, respectively.

In a typical man-machine-environment system, level of desired performance may be considered an approximate "constant" which in some cases is established by the human operator, in others established by the system-defined goal or purpose. When demands for energy expenditure occur due to increased load imposed on automatic processes, a conflict between the desire to minimize energy expenditure and the desire to maintain a given level of performance is proposed to emerge. The resolution of this conflict may be referred to as "coping".

Since mandatory processes prioritize allocated energy, any attempt by the central processor to minimize energy expenditure must be directed toward task-related purposive processes. In other words, while the central processor must grudgingly allocate demanded energy resources to non-task-related automatic processes, it, simultaneously, requires purposively active subsystems to minimize energy requirements. Efficiency is defined as the cost in energy per unit performance achieved.

With very little effort and few flights of fancy, the above notions could be applied to give an energy-oriented explanation of the progress of skill development. Energy conservation is the biologically significant motive for increased skill. The parallel process described here asserts that efficiency is dictated by a biologically significant requirement to minimize energy expenditure at any given moment in time. The parallel described above is central to this treatment.

If the above notions are true, then, one would expect that within processing capacity, increases in mandatory subsystem load should result in both an increase in total rate of energy expenditure and an increase in the efficiency with which purposive subsystems generate desired performance. There should, of course, be an upper limit of efficiency attainable by a given purposive subsystem configuration; such configurations are referred to here as behavioral sets.

Assuming mandatory subsystem requirements continue to increase unabated, while purposive subsystem efficiency has asymptoted, the

limits of processing capacity will at some point be reached. At this point, the reduction in energy allocated to purposive subsystems results in a performance decrement.

Thus, as less and less energy is available due to the priorities of increasingly activated automatic subsystems, the task related processes approach maximum efficiency while maintaining high levels of performance. At some limiting level of overall system activation, the energy demands for optimal performance of task-related processes can no longer be met with the residual energy available after mandatory subsystem demands. At this point performance begins to suffer and, at some critical level of such performance decrement, the organism/operator may select to shift his task-related processing strategy (behavioral set) or may be forced to do so as automatic subsystem activity interferes with task-related processing, forcing data deficiencies and/or overloading.

The shift is proposed to involve a downward hierarchical shift to previously learned, lower-quality-of-performance-generating combinations of perceptual, cognitive, and motor behavior. These lower hierarchical behavioral sets are proposed to require less total energy, generate lower levels of performance and to generally be less efficient, but are more applicable given the task-related energy available. The result is the treatment of the task as less complex, allowing a higher level of arousal acceptable prior to additional performance decrement and the beginning of the whole cycle again as arousal (a function of total stimulation) continues to increase.

Central to the above proposed conceptual framework is the notion that the progress of stimulation/load effects parallels patterns of behavior and performance exhibited during learning. Increasing stimulation/load beyond some capacity limit is proposed to reverse behavioral and performance patterns exhibited during learning. Progression involves upward shifts through hierarchical stages and increased efficiency of task-related processing once performance stabilizes to the optimal range within a stage as arousal increases. Regression involves decrements in performance due to downward hierarchical shifts, with decreases in efficiency only as these shifts occur. Each hierarchical stage is proposed to have its own limiting level of optimal performance and its own increasing efficiency function of increasing arousal associated with stage-specific optimal performance.

More complex tasks are proposed to result in higher initial levels of arousal associated with their higher stimulation/load characteristics. In terms of the above conceptual framework, complex (versus simple) tasks are closer to the limiting capacity involved in determining the range of arousal over which increased efficiency occurs and, of course, are therefore more likely to result in performance decrements and downward hierarchical shifts. Stated differently, the range of non-task stimulation/load consistent with optimal performance is smaller for complex tasks than for simple tasks.

Operationally defining and measuring efficiency may be a formidable challenge to the extent that perceptual and cognitive processes are not for the most part directly observable. However, outputs of

motor processes are directly observable; such motor outputs may be measured in their entirety as continuous wave forms or as discrete summaries with measures of specific parameters of the motor response waveforms as functions of time. For any given level of task performance, assuming that the progress of skill development is indeed toward greater efficiency, patterns of motor activity, measured as a function of time in training, may provide indices of progression. While a most direct interpretation of progression-with-training would predict a general reduction in motor activity as skill develops, this would make the unsubstantiated assumption that the progress toward maximum efficiency involves modification of motor processes only. A more reasonable approach would involve the examination of trends in motor activity as skill develops and, given stabilized levels of performance, the determination of what, if any, systematic modifications take place. It is proposed that whatever trends do emerge reflect the underlying modifications toward more efficient energy utilization within a given hierarchical stage of skill development.

Several models of human performance include possible operations involved in both increased and decreased efficiency of task-related processing. Such models often include conceived processes related to stimulus-stimulus and stimulus-response translations, serial vs. parallel processing, chunking, blocking, and filtering operations. While most of the above may be regarded as residing in the "cognitive domain", their influences extend to both perceptual and motor processes and are not inconsistent with this treatment; they differ only in



degree of elaboration and locus of primary interest and can each be translated to conform to a biologically significant, efficiency-oriented framework.

This treatment has intentionally, for present purposes, not addressed multiple-task situations which could involve direct interference with the inferred primary perceptual, cognitive, and motor processes involved in primary task performance. One alternative explanation for "regression-like" effects as a function of increased non-task stimulation, however, should be addressed. This explanation involves the possibility that physiological "shaking" might result in the proposed increased control activity and, thereby, degraded performance under the conditions proposed above.

Physiological "shaking" is a common response to exposure to physically and/or psychologically stressful situations. It involves apparent involuntary innervation of large muscle groups and often is associated with relatively high amplitude, high-to-moderate frequency, asymmetrical limb displacement. Its amplitude, frequency and phase response patterns distinguish it from physiological "tremor", which could have little impact on the parameters discussed here in relation to high-order control systems.

While it was not anticipated that the arousal conditions generated for this study would precipitate such extreme stress reactions, a few observations are offered here which relate primarily to the expected conditions under which such responses might be expected and methodo-

logical approaches toward discriminating regression versus "shaking" effects.

If arousal is considered along a single continuum from an extreme low to an extreme high, deactivation/sleep and hyperactive spasmodic behavior would be expected to reside at such extremes, respectively. Somewhere between these two extremes should reside states of activation consistent with purposive man-machine interface, thus "performance". Physiological research and operational experience provide evidence that what is extreme stimulation to one individual, may have no apparent effect on another; thus, strong individual differences are noted. Barring the occurrence of specific phobic reactions, individuals trained in the operation of complex control systems (e.g., professional pilots) constitute select populations that are less likely to slip into extreme arousal reactions in the presence of moderate to moderately high levels of stimulation. This does not, however, make them immune to "regression" effects or secure them from possible physiological "shaking" effects.

The regression effects proposed here are argued: 1) to occur "earlier" in the progress of arousal effects than would physiological shaking, 2) to be more subtle in onset, and 3) to be much more amenable to voluntary intervention. Thus consideration of subject population characteristics, the nature of the stimulus conditions involved, and the effects of attempted voluntary intervention should constitute first steps in discriminating the effects in question. Further, physiological shaking, unlike regression effects, should

continue beyond task involvement. This last observation should provide a direct operational check to assist in resolving ambiguity. Where increased control activity does not occur with increased stimulation, this question has no apparent bearing.

In summary, then, in the context of a purposive man-machine system, level of activation/arousal is a function of task complexity and all other environmental physical and symbolic stimulation. Level of momentary performance is some function of level of arousal/activation and level of skill development which dictates some degree of task efficiency reflected in concomitant behavioral patterns. Given some level of skill development, level of arousal is proposed to dictate the hierarchical stage in operation, the level of efficiency within that stage, and, thereby, the level of performance at any given moment in time. Excessive and insufficient activation are proposed to result in regression in behavioral patterns toward less efficient patterns previously demonstrated during skill development. While operating within the organism's limited processing capacity, increased arousal should dictate increased efficiency; beyond the organism's limited processing capacity, increased arousal should result in decreasing efficiency as performance declines.

#### Related Findings

Fuchs (1962) offered support for a progression-regression hypothesis. This hypothesis relates changes in components of behavior during skill development to changes associated with the imposition of load, in his experiment, application of a secondary task. Subjects demonstrated

a "progression" during training. Early in training, subjects generated discrete, reactive, error-amplitude-based response patterns in a single axis compensatory tracking task with second-order (acceleration) control dynamics; later, subjects reduced error and produced complex projective, velocity- and acceleration-based response patterns as skill developed. This trend continued even after performance had asymptoted consistent with Welford's (1973, 1979) concept of skill development. When a secondary zero-order tracking task was imposed, which Fuchs called a task-stressor, subjects demonstrated a "regression" toward amplitude-based response patterns and a concomitant decrement in performance in the primary task.

While Fuchs' application of a secondary task imposed attention-shifting requirements which could have resulted directly in a more discrete sampling, therefore, a more reactive, amplitude-based response strategy due to a perceptual data limitation, the concept of a progression-with-learning/regression-through-stress is worthy of consideration and experimental examination. The reason offered for the worth of such consideration is that, for a large class of tasks involving graded responses, control device manipulation (control activity) defines performance. Fuchs did, at the very least, establish that trends in control activity exhibited during training could be systematically related to trends in control activity when additional "load" is imposed on the human "controller". The conceptual leap required to go from "load" as a secondary task to "load" as imposed in traditional stress studies, while not trivial, is a most reasonable one. Such a leap may

provide valuable information toward clarifying the relationships between arousal and performance. A clearer examination of the hypothetical model proposed earlier should, however, avoid the potentially confounding influence of an "additional load" which can directly interfere with primary task-related perceptual, cognitive, and motor processing as might a secondary task.

Pilots in extremely situationally threatening environments (high speed, low-level, night-time, contour flying operations) have been informally observed by this investigator to demonstrate "less smooth" control movement activity than was typical under "normal" situational conditions. Thus, these pilots seemed to react to situational stimulation in much the same way as Fuchs' subjects did to the introduction of a secondary task; it was this observation which most directly prompted this investigation.

That "efficiency", or minimization of control manipulative activity, is a typical product of skill development in higher-order control systems has been demonstrated in the laboratory. Hunt (1959) observed that integrated absolute control displacement, IACD, (effectively, a measure of average amplitude of control movement per unit time) seemed to diminish with practice and that the amount of decrease was greater for easy than for difficult tasks. Since "difficult" tasks involved an increased frequency of a sinusoidal forcing function, a floor-effect interpretation may explain the smaller apparent decrease for difficult tasks.

Diamantides (1958) demonstrated that pilots operating complex flight control systems tended to improve or increase "information feedback" about controller dynamics by injecting a signal into the loop in a compensatory-tracking task. The injected signal took the form of dither (a high-frequency, low-amplitude control movement strategy) or discrete overcontrol inputs. Such control activity aided subjects in the inference of the characteristics of the forcing function versus the control dynamics of the machine system. Diamantides noted that this behavior extinguished with learning and was more apparent in the unskilled.

Poulton (1963, 1974) noted that a small percentage of subjects using a higher-order control system produced dither. He suggested that this behavior may have enabled the subject to feel more in control of the tracking (situation) or to effectively reduce the order of the control system at the cost of increased motor activity. The above findings support the contention that skill development in compensatory tracking systems with second-order control dynamics involves a reduction in control activity.

#### Statement of the Problem and Methodological Considerations

Experimentally evaluating all the implied hypotheses associated with the conceptual framework proposed earlier must involve the manipulation of both arousal and performance. Since the manner in which individuals cope with changing arousal may affect system goal accomplishment and survival of the system (which includes man), the identi-

fication of behavioral variables which might be adjusted to augment system performance is a worthy endeavor.

Lawrence (1976) attempted to diminish usual decrements in tracking performance due to increasing arousal through biofeedback training involving heart rate (HR) regulation. While subjects with feedback training were able to control HR changes normally associated with the arousal-inducing manipulations employed during a tracking task, performance decrements did not differ significantly between groups with and without such training. Bradley, Cox and Mackay (1977), in one of several conditions tested, demonstrated that behavioral responses can be enhanced by altering the physiological response. By preloading subjects with glucose, these investigators were able to attenuate the detrimental effects of an auditory noise manipulation on tracking performance.

Questioning the operational practicality of Bradley, Cox and Mackay's approach and the task-relevance of Lawrence's, the implications of Fuchs' proposition, offer an alternative approach to performance augmentation. Fuchs' work suggests that behavioral trends during skill development may be reflected in behavior/performance changes due to changing load. Welford (1973) and Cox (1979) related load to arousal and to performance effects. If behavioral changes during skill development such as those cited by Diamantides, Fuchs, Hunt, and Poulton can be meaningfully related to effects of arousal on performance, then behavioral feedback techniques might be used within the tracking task to rechannel the effects of arousal in desired direc-

tions. Rupp (1974) demonstrated that subjects could be trained to modify specific patterns of tracking behavior and, within ranges of specified parameter values, the application of such training resulted in optimal performance.

The objectives of this research then were: (a) to measure behavioral parameters which prior research findings suggest change systematically with training; (b) to manipulate arousal and to measure concomitant performance trends; (c) to test hypotheses relating trends in selected behavioral parameters to trends in performance as functions of increasing arousal; and (d) to examine the findings in relation to the proposed conceptual framework.

Lacey et al. (1952), Lacey and Lacey (1958), and Lazarus (1966) have reported high intersubject and interstimulus (within subject) variability in measured arousal responses. Based on these and similar findings, Lazarus (1966), Lazarus et al. (1963), and Mandler (1959) have recommended a within-subjects manipulation of stimulus conditions; this recommendation was followed in this study. Since a meaningful ordinal relationship between arousal conditions was central to this investigation, levels of arousal (associated with levels of stimulation) were operationally verified based upon a combination of physiological measures and subject checklist indices.

In an attempt to generate different levels of arousal, a basic masking noise (M) was combined with loud auditory noise (MN) and with the loud noise plus competition/threat (MNC), resulting in three arousal conditions. Each of these experimental arousal conditions



(M, MN, and MNC) was combined with each of three levels of task difficulty in a complete factorial design. The use of noise as an arousal manipulator is common in the literature and is suggested to be most effective in the context of complex psychomotor tasks (Glass & Singer, 1972; McCormick, 1976).

Overall system performance was quantified in terms of tracking error scores consistent with the task description given to the subjects; these scores were given as performance feedback throughout training. Behavioral measures (control activity measures) were selected to reflect expected trends in training, confirmed in pre-testing, and on the basis of their ease of measurement and potential applicability to behavioral feedback training.

#### Hypothesized Relationships

Three basic categories of hypotheses emerged from the above discussions. The first category addressed the effects of manipulated levels of stimulation (arousal conditions and levels of task difficulty) on traditional measures of arousal/activation. The second related to the effects of levels of stimulation on performance. Specifically, this second category addressed the reliability of arousal condition and task difficulty effects on performance. The final category addressed the reliability of arousal condition effects on control activity measures employed. This final category also examined the reliability with which the measures employed discriminated level of task complexity as defined in this study.

Arousal measures and levels of stimulation. To clarify the relationships between traditional measures of arousal and both level of task-load (level of task difficulty) and level of non-task-load (arousal condition), skin resistance and subject self-report measures were used in this study as operationally defined indices of arousal. Increased task complexity and non-task stimulation were predicted to result in increased measured arousal.

Arousal conditions and performance. The hypothesized relationships between arousal and control activity were dependent upon the manner in which arousal conditions affected performance. If performance improved or remained stable as arousal increased, this was interpreted to indicate that processing capacity had not been exceeded. If performance declined as arousal increased, the interpretation was that processing capacity had been exceeded. It was predicted that the likelihood of exceeding processing capacity should increase with task complexity. Operationally the above was hypothesized as a predicted interaction between task complexity and arousal condition.

Control activity measures and arousal conditions. A hierarchical view of skill development and the effects of arousal implies that increased arousal first affects efficiency, followed closely by performance. Operationally defining "increased efficiency" (in the specific context of the second-order compensatory tracking task employed) as a reduction in the amount of control activity employed for a given level of performance in a task, one should expect increased efficiency with

increased arousal while within the operator's processing capacity indexed by increasing or stabilized performance.

The inverse prediction was also held to be true; increased arousal should result in reduced control activity efficiency when capacity is exceeded, as indexed by decreasing performance trends. Again, as with performance predictions above, given a sufficient effect of arousal manipulations, an interaction of arousal manipulations, and task complexity was proposed. Further, since it was intended that, if appropriate, the control activity measures employed might be operationally useful in predicting performance, reliable effects of difficulty (greater activity with greater difficulty) and arousal conditions (specific direction dependent upon performance trends) were predicted. Mean trends in performance across arousal conditions were examined to determine the appropriate predictions relating control movement activity to increasing non-task load (increasing arousal condition stimulation).

## Method

### Subjects

Twelve male AFROTC cadets, ages 18-23, physically qualified for flying training, were randomly selected from a group of 19 volunteers to participate in this experiment. No monetary incentive was provided or expected by the subjects prior to experimental participation.

### Apparatus

Primary functional units. Experimental equipment consisted of four primary functional units:

1. The control: The control element was a lightly spring-centered joystick, 9 cm long, collared to operate only in the fore-aft dimension from vertical relative to the operator. Fore-aft motion corresponded to down-up moving display index response. Full deflection corresponded to  $\pm 36$  deg of arc and 6.5 cm/sec maximum acceleration. Commanded acceleration was a linear function of control displacement (see Appendix A, Figure 7). The joystick console was located at mid-line between the subject's knees and could be adjusted in height for subject comfort.

2. The display: A Hewlett Packard 130 BR oscilloscope with an etched black grid, whose readily identifiable horizontal centerline acted as the fixed command index, displayed a single scope-width horizontal luminous line as the moving index. With the exception of the circular scope face and a trace centering knob, the rest of the unit was covered with a flat black mask. The scope face was 14 cm in diameter and was located approximately 52 cm in front of the subject

when tracking. The black grid presented no parallax problems and was graduated in 1-cm square cells in a 10 x 10 square matrix with easily discriminable horizontal and vertical centerlines. Two .4-cm lights, one red and one green, located above the scope face midline provided system status information for subjects.

3. A hybrid digital-analog kluge: A digital-analog electronics package, called "ACK" performed the following functions (see Appendix A, Figure 8):

- a. generation of .6-sec time delay and subsequent double integration and scaling of joystick inputs for second-order control dynamics.
- b. digital storage of sinusoidal forcing function (8192 data points, summation of fundamental, first- and inverted fourth-harmonics, see Appendix A, Figure 9) and allowance for computer selection of sampling rate to control task difficulty and start point of sampling.
- c. accumulation of integrated absolute error, IAE, the measure of overall performance.
- d. accumulation of integrated absolute control displacement, IACD.
- e. accumulation of integrated absolute control velocity, IACV.
- f. digital count of control movements exceeding a velocity of 36 deg/sec, threshold velocity count, TVC.
- g. measurement of absolute skin resistance in analog form (appropriate subject interface, constant current system @ 10 mA).

- h. sampling of analog signals for digital conversion.
- i. generation of switch selectable auditory signals: steady at 75 dB(A); or periodic @ 15 cpm 75 dB(A) to 100 dB(A) triangle wave; or voice communication, experimenter to subject.
- j. control of internal functions as directed by the controlling computer.

4. The controlling computer: An APPLE II microcomputer was used to control the experiment. The computer:

- a. supplied command information to ACK.
- b. sampled and digitized outputs of ACK.
- c. timed all tracking measurement periods.
- d. provided experimenter with performance feedback information via a video display and provided a command control keyboard for experimental and training manipulations.
- e. interfaced with a floppy disc system for data storage and subsequent retrieval for analysis.

Experimental setting. Subject and experimenter were in separate rooms. A one-way window allowed the experimenter to observe the subject throughout experimental and training sessions. The experimenter communicated with the subject via a switch-operated microphone. The subject wore Telex 1470 headphones at which all auditory noise levels were measured prior to experimental application. The subject was seated in a modified dentist chair and two Beckman Ag/AgCl standard electrodes were attached to the medial aspect of the subject's right foot over the abductor hallucis muscle. A tape mask (water impermeable

two-sided adhesive) allowed adjacent electrode placement and controlled skin surface (1.3 cm diameter per hole for @  $7.5 \text{ mA/cm}^2$ ) (Edelberg, 1967; 1972). A locally manufactured heel rest with adjustable inclination maximized subject comfort and minimized external pressure and movement artifacts.

Forcing function. A single cycle of a sinusoidal forcing function, FF (summed fundamental, first-, and fourth-harmonics, fourth-harmonic 180 degrees out of phase), was digitally stored as 8192 data points in ACK. Task difficulty was manipulated by varying the rate at which the stored function was sampled. Sampling at 3 ms, 5 ms, and 9 ms-intervals resulted in frequencies of approximately 2.44 cpm, 1.46 cpm, and .81 cpm and periods of 24.6, 41, and 73.7 seconds, respectively, for the difficult, medium, and easy conditions. Maximum amplitude was set at  $\pm 5.5$  cm and three starting points at zero-crossing were selected for random application in the experiment (see Appendix A, Figure 9).

Scoring. The basic measurement period duration through training and experimental sessions was 24.6 seconds (corresponding to the period of the FF in the fast condition). For brevity, each of these measurement periods is hereafter referred to as a "trial". A "mission segment" is defined as a string of 11 trials, the first and last with no FF. Appendix A, Figure 10 illustrates a single-trial and a mission segment mode FF. The central nine trials of a mission segment consisted of three trials at each level of difficulty, each with a different start point on the forcing function. The sequence of these levels

of difficulty and start point combinations was randomly generated. Prior to and after each of the trials in a mission segment was a non-measurement period of 12.34 seconds during which the subject was required to continue to null error against no FF. For the subject, then, a mission segment was a 6-min 58-sec continuous tracking task which was described to him as a contour flying task over varying terrain elevations.

At the end of each trial, in the single-trial (primary training) mode of operation, tracking error (IAE), control activity (IACD, IACV, and TVC), and average skin resistance (ASR) measurements were presented to the experimenter on his video display for manual recording. (See Appendix B for a description of the specific measures taken.) In the "mission segment" mode of operation the same data were provided after each trial and automatically stored. A summary of all data was generated on the video display, appropriately collated by level of difficulty, at the end of each mission segment.

#### Procedure

Subjects participated in two training and one experimental session on three consecutive days at the same time of day per subject  $\pm 1$  hour for Days 2 and 3 (a suggested control for diurnal effects, Venables & Christie, 1973). Time of day varied between subjects as a function of class schedule constraints. A sample of the subject Volunteer Sheet/Schedule is presented in Appendix C, Figure 11.

Training, Day 1, involved attachment of electrodes, standard instruction, and 40 (single-trial mode) practice trials, 10 each at each



level of difficulty of the FF including the first 10 with no FF. Subjects listened to the 75 dB(A) masking noise throughout the session and received verbal feedback (IAE) after each trial. Intertrial intervals were approximately 90 sec within each level of difficulty and approximately twice that between the blocks of 10 trials. The sequence of blocks was one of increasing task difficulty. The Day 1 session lasted approximately two (2) hours from subject arrival to departure.

On training Day 2, subjects received a block of 5 trials with no FF, followed by 4 trials with the easy, 5 trials with the medium, and 6 trials with the fast or difficult forcing function. After these 20 trials, standard instructions concerning the nature of a mission segment were given. Two mission segments were then run to acclimate the subject to the format to be used on Day 3. The subject once again wore the electrodes and listened to the masking noise while tracking. Tracking error feedback was provided after each of the first 20 trials and after each of the two mission segments. On Day 2, all subjects received the same sequence of FF difficulty and start points for the two mission segments flown. The Day 2 session lasted approximately 1.5 hours.

The experiment, Day 3, involved the running of three identical mission segments per subject. Each subject was randomly assigned to his unique mission segment sequence for Day 3. Each segment was flown under a different arousal condition. Two subjects were randomly assigned to each of the possible sequences of three arousal conditions employed. The three arousal conditions included:

1. A masking-noise-only condition (M) prior to which the subject was encouraged to do his very best and then performed the task under conditions with which he was very familiar. This manipulation was operationally defined as the "low" level of non-task stimulation.

2. A masking-plus-loud-noise condition (MN) prior to which he was informed that he would hear noise over headset intended to simulate some of the noise he could expect to hear when flying a high-performance aircraft in the dense air near ground level. He was then encouraged to do his very best and flew the segment in oscillating 75 dB(A) to 100 dB(A) noise. This manipulation was operationally defined as the "moderate" level of non-task stimulation.

3. A masking-plus-loud-noise-plus-competition condition (MNC) prior to which the subject was informed about the noise as above and further informed that his performance on this segment and this segment only would be entered in competition with his peers for a \$50 bonus to be paid to the best tracker. He was informed that his performance was already among the best but that competition was keen. In addition, he was informed that his tracking scores from this segment and this segment only would be posted at the AFROTC unit along with his peers' scores. He was encouraged to do his very best and then flew the segment with the oscillating noise as above. This manipulation was operationally defined as the "high level" of non-task stimulation.

Upon arrival for the experiment, Day 3, the subject was asked to fill out a Thayer Activation/Deactivation Adjective Checklist (see Appendix C, Figures 12a and 12b). He also completed one immediately

following each mission segment to reflect his feelings during the mission segment and one after his debriefing at the end of the experimental session. Prior to and after each mission segment, after he completed the checklist, the subject was asked to relax, fixated on a specific location; two minutes later a reference average skin resistance measure was taken as a covariate to examine resistance readings for any systematic time trend variations. The elapsed time between each mission segment (i.e., arousal condition manipulation) was approximately 10 minutes. The experimental session lasted approximately one hour.

## Results and Discussion

Analyses were conducted in three phases to correspond with the categories of hypotheses previously proposed. Analyses of variance were calculated for each dependent measure with subsequent orthogonal contrasts based on findings of specific interest (Meyers, 1979). In addition, preliminary regression and correlation analyses were conducted to further clarify selected relationships.

### Traditional Arousal Measures and Levels of Stimulation

Levels of difficulty and skin resistance scores. To control for unsystematic effects of tonic shifts, time trends and the high variability of initial values, a covariate technique proposed by Lacey (1956; in Sternbach, 1966) was applied to generate skin resistance autonomic lability scores, SR(ALS). The computation requires a pre-stimulation score and a corresponding autonomic response score per measurement period.

A pre-stimulation skin resistance score (PSR score) was operationally defined as the first absolute skin resistance measurement taken during a measurement period. This measure was assumed to be free of level-of-difficulty effects since it was taken before the specific level of difficulty for a trial could effect a skin resistance response (i.e., at time zero of the measurement period). The (level of difficulty) response was defined as the average absolute skin resistance measured over the period, ASR.

Assumptions underlying the applicability of the autonomic lability score computation include normality of the distributions of PSR and ASR

over all subjects and conditions and a linear relationship between these two measures. Two subjects (7 and 9) exceeded equipment skin resistance measurement limitations and their data were not included in any subsequent analyses involving SR(ALS).

Fisher's test for normality of untransformed data (Johnson, 1949) indicated no significant departure from normality for either PSR or ASR distributions in terms of skewness ( $\underline{t}_{\infty} = .561$ ,  $p \leq .56$ ; and  $\underline{t}_{\infty} = .142$ ,  $p \leq .87$ ); however, PSR reliably deviated from normality ( $\underline{t}_{\infty} = 1.98$ ,  $p \leq .048$ ), while ASR did not ( $\underline{t}_{\infty} = 1.95$ ,  $p \leq .051$ ) in terms of kurtosis. For purposes of this application, however, the respective distributions were considered acceptable. A Pearson-product-moment correlation between PSR and ASR of  $\underline{r} = .976$  ( $\underline{r}^2 = .953$ ) was computed. An analysis of variance test for linearity indicated a reliable linear relationship,  $\underline{F}(1,2) = 12484.42$ ,  $p \leq .0001$ , between the two variables. The required transformation is given by:

$$SR(ALS) = 50 - 10 \frac{\frac{\underline{Y}}{\underline{Z}} - \frac{\underline{X}}{\underline{Z}} \underline{r}}{(1 - \underline{r}^2)^{\frac{1}{2}}};$$

where  $\frac{\underline{Y}}{\underline{Z}} = z$  transform of ASR,

and  $\frac{\underline{X}}{\underline{Z}} = z$  transform of PSR

As described by Sternbach (1966), Lacey's procedure corrects for the Law of Initial Values and permits comparison of patterns of response between individuals (across several physiological measures) or for one person on several occasions. The ALS scores have several desirable

properties including the effective removal of initial value effects and an increased weighting of responses at extreme (low) tonic levels. For purposes of this experiment, the procedure provides a clear discrimination of level of difficulty effects, theoretically free of arousal condition main effects.

Figure 3a presents mean SR(ALS) as a function of the levels of difficulty and Figure 3b further breaks down the means by arousal condition. Analyses of variance results are presented in Table 1a and 1b corresponding to the figure presentations. As may be noted, there was a reliable effect of difficulty on SR(ALS),  $F(2,18) = 5.88$ ,  $p \leq .05$  in the predicted direction (i.e., higher scores with greater difficulty). The general pattern is consistent for all arousal conditions. As expected due to the ALS procedure, there was no main effect of arousal conditions. Linear contrasts, presented in Table 1c, indicate no reliable difference in effect of the easy and the medium levels of difficulty on SR(ALS),  $F(1,18) < 1$ , but a highly reliable effect of the difficult condition,  $p(F) < .001$ . This result suggests that, while easy and medium difficulty manipulations influenced performance and control activity differently (results to be presented later), they failed to be indexed as reliably different by SR(ALS).

One explanation for the above results is suggested from subject observations recorded after the experiment. Subjects stated that during the easy condition they clearly defined "acceptable performance" as the maintenance of error as close as possible to zero-error, a fairly clear-cut and stringent performance criterion. During diffi-

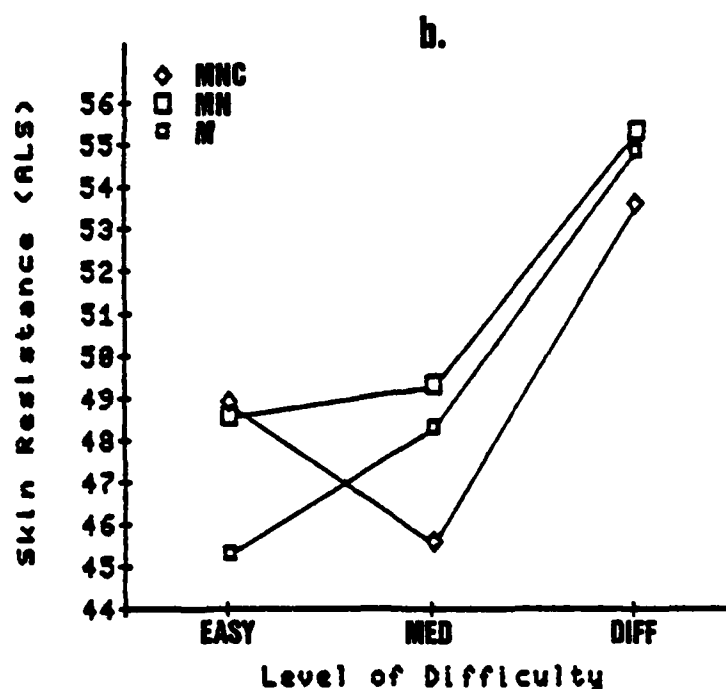
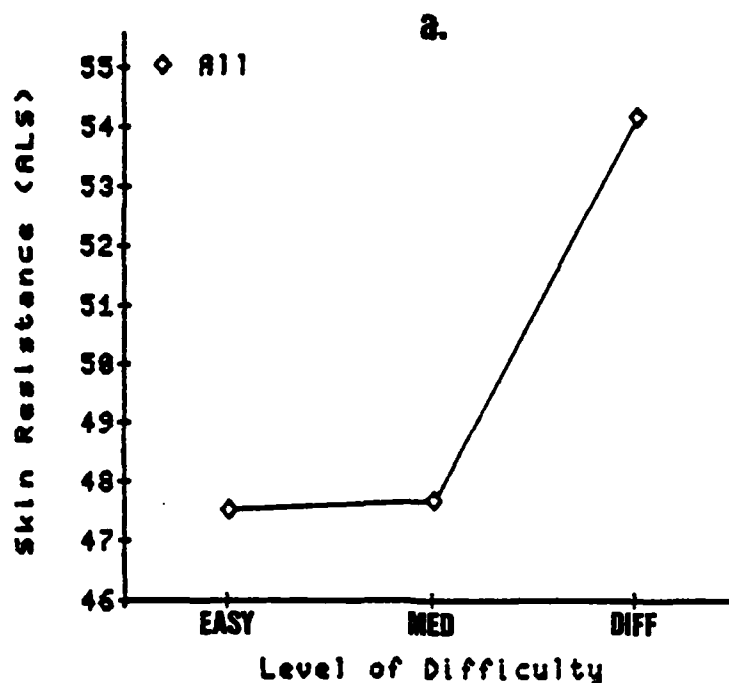


Figure 3. The effects of levels of difficulty on Skin Resistance (Autonomic Lability Scores), SR(ALS). The ALS computational formula inverts SR score interpretation; thus, higher SR(ALS) scores provide indices of increased arousal/activation. a. Each point represents the mean score of replications, 3, arousal conditions, 3, and subjects, 10 (i.e.,  $n = 90$ ). b. Each point represents the mean score of replications, 3, and subjects, 10 (i.e.,  $n = 30$ ).

Table 1a

Summary of Analysis of Variance for SR(ALS)  
Excludes Subjects 7 and 9, Complete Model.

SV	df1,df2	MS	F
Arousal(F)	2,18	74.87	1.30
Difficulty(F)	2,18	1286.90	5.88*
Subjects(R)	9,180	224.81	2.61*
AxD	4,36	77.11	2.01
AxS	18,180	57.63	.67
DxS	18,180	218.79	2.54**
AxDxS	36,180	38.45	.45
Replications (R)/AxDxS	180, -	86.03	-

(F) = fixed variable; (R) = random variable

\* $p \leq .05$ ; \*\* $p \leq .01$ ; \*\*\* $p \leq .001$

Table 1b

Summary of Analyses of Variance for SR(ALS);  
Partitioned Data, Models Conditional on Arousal Condition.

SV	df1,df2	M		MN		MNC	
		MS	F	MS	F	MS	F
Difficulty(F)	2,18	639.62	4.80*	370.06	6.35**	431.44	4.14*
Subjects(R)	9,60	157.12	1.09	110.63	2.04	72.31	1.22
DxS	18,60	133.31	.92	58.26	1.08	104.11	1.76
Replications (R)/AxDxS	60, -	144.67	-	54.11	-	59.30	-

(F) = fixed variable; (R) = random variable

\* $p \leq .05$ ; \*\* $p \leq .01$ ; \*\*\* $p \leq .001$

Table 1c

Summary of Selected Orthogonal Linear Contrasts for Effects  
of Levels of Difficulty on SR(ALS). Excludes Subjects 7 and 9.

Contrast	df2	SS	F
EASY vs. MED	18	1.13	.01
EASY+MED vs. DIFF	18	2572.67	11.76**

\* $p \leq .05$ ; \*\* $p \leq .01$ ; \*\*\* $p \leq .001$



cult trials, subjects reported an equally clear-cut and stringent criterion to maintain system control; all subjects reported that maintaining the moving index on the scope face was a challenging activity. During medium level of difficulty trials, however, subjects reported a less stringent, more flexible criterion; they generally accepted that they could not approach zero-error but had little difficulty in maintaining system control. Thus they were free to set their generally applied criterion of minimum error wherever it happened to fall.

While supposedly the medium level of difficulty generated more task defined load, it may not have been perceived to be as challenging as the easy level; this might explain the ambiguous discrimination of easy versus medium conditions in obtained SR(ALS) means. Examination of individual subject mean plots across levels of difficulty suggests that the primary source of the reliable subjects-by-difficulty interaction,  $F(18,180) = 2.54$ ,  $p \leq .01$ , was indeed between easy and medium levels of difficulty.

Arousal conditions and the Thayer Checklist. The Thayer Activation/Deactivation Adjective Checklist was used to provide a traditional measure of arousal condition effects. The checklist demonstrates high test-retest reliability (on the order of .9, Thayer, 1967, 1978) and reliable correlations ( $r = .5$ ) with combined physiological measures (Eysenck, 1975, 1976). For each subject an average score for each of four factors for each arousal condition in this experiment was calculated. The four factors included: (a) General Activation (G Act); (b)

High Activation (H Act); (c) General Deactivation (G Deac); and (d) Deactivation Sleep (D-Sl).

For each subject, at each arousal condition, each average factor score was converted to a z score based upon each subject's distribution of items scores for each factor across arousal conditions. Each z score was then weighted based on the number of checklist items Thayer applied to evaluate each factor. The weighted z scores were summed across factors (within each arousal condition) and divided by the sum of weights.

The resulting z scores, Thayer Checklist z scores, provided a single index of arousal per condition (3) per subject (12). To simplify plotting and computations, each of these scores was arbitrarily scaled in a fashion similar to that applied to generate SR(ALS) and are referred to as Thayer Checklist Scores (TCS).

An analysis of variance, summarized in Table 2a, indicated a reliable effect of arousal conditions on TCS in the predicted direction,  $F(2,22) = 6.6$ ,  $p \leq .01$ . Orthogonal contrasts, summarized in Table 2b, indicated no reliable difference between the M and MN treatments,  $F(1,22) \leq 1$ , and offer no statistical support of a possible reversal of predicted increased non-task stimulation effects as might be suggested by Figure 4. While the Thayer self-reports generally and reliably confirmed the high-arousal effect of the MNC manipulation, the relationship between M and MN conditions as indexed by TCS is unclear.

One explanation may be found in subjects' post-experimental assertions that the noise manipulation "had no effect" or "helped me to

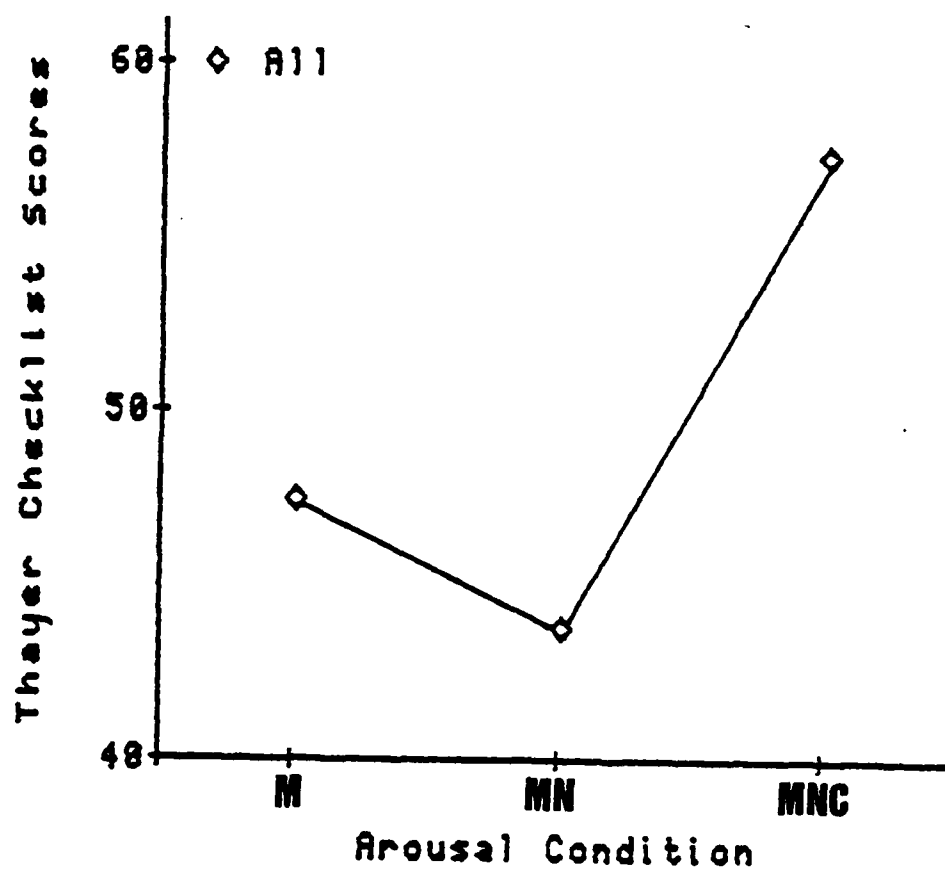


Figure 4. The effects of arousal conditions on Thayer Checklist Scores, TCS. Each point represents the mean score of subjects (i.e.,  $\bar{n} = 12$ ).

Table 2a

Summary of Analysis of Variance for TCS; Complete Model.

SV	df1,df2	MS	F
Arousal(F)	2,22	591.39	6.60**
Subjects(R)	11, -	.09	-
AxS	22, -	89.65	-

(F) = fixed variable; (R) = random variable

\* $p \leq .05$ ; \*\* $p \leq .01$ ; \*\*\* $p \leq .001$ 

Table 2b

Summary of Selected Orthogonal Linear Contrasts for Effects of Arousal Conditions on TCS; Complete Model.

Contrast	df2	SS	F
M vs. MN	22	82.91	.92
M+MN vs. MNC	22	1099.87	12.27**

\* $p \leq .05$ ; \*\* $p \leq .01$ ; \*\*\* $p \leq .001$

focus my attention." Only one subject stated that the noise manipulation "definitely bothered" him. The subjects employed in this study were apparently highly motivated and generally reflected high apparent levels of confidence. Most of them vigorously opposed the suggestion that "a little noise" could have affected their behavior. It is suggested that the perceived effects of the noise manipulation as reflected in the Thayer checklist may have been influenced by a generally defensive attitude. Cox (1979) has argued that distinctions should be made between actual versus perceived demand and the above result would seem to support such a contention.

#### Experimental Manipulations and Performance

A common log transformation was applied to IAE scores to more appropriately conform to the assumptions of the analysis of variance. Figure 5 and Tables 3a and 3b summarize the obtained results. As intended, higher levels of difficulty resulted in reliably higher tracking error scores,  $F(2,22) = 147.25$ ,  $p \leq .001$ . The arousal manipulations applied in this study failed to reliably affect performance,  $F(2,22) < 1$ , and a subjects-by-arousal interaction only achieved reliability for difficult trials. Experimental manipulations also failed to generate the predicted arousal by difficulty interaction,  $F(4,44) < 1$ , supporting an interpretation of a relatively small or no arousal condition impact on performance as measured. An examination of grand means across arousal conditions suggests a slight downward trend in LIAE.

The relative consistency of the suggested, though weak, upward trend in performance (decreasing LIAE) for all levels of difficulty,

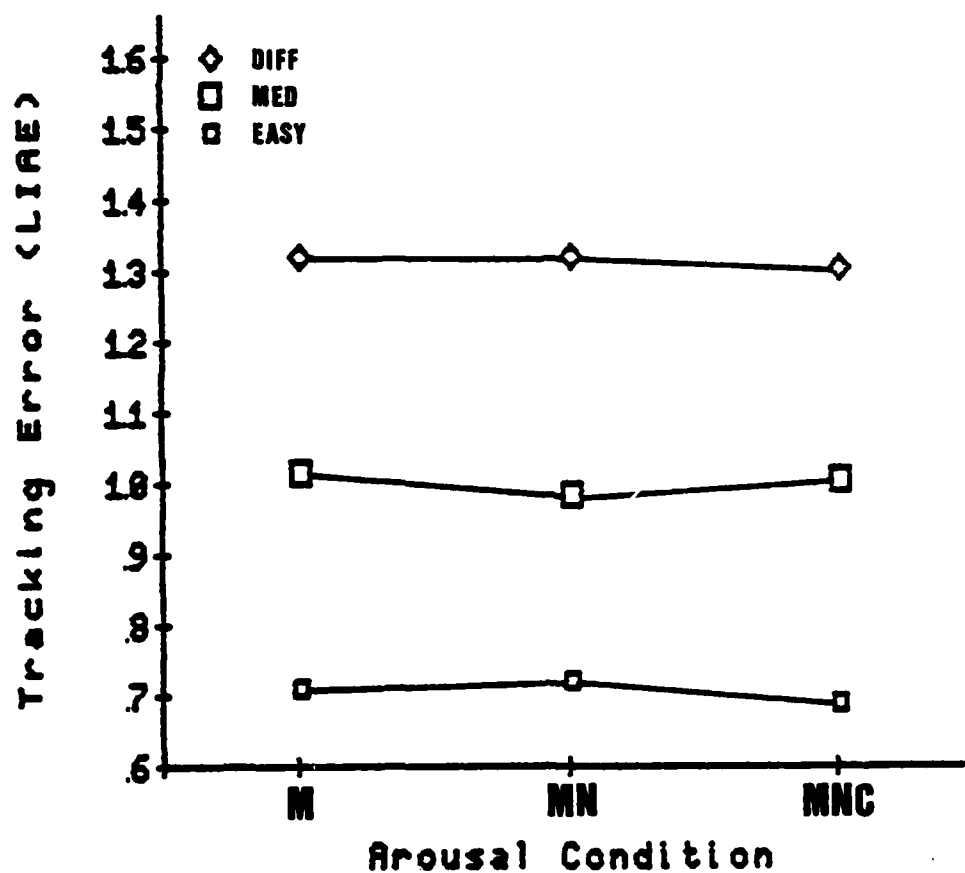


Figure 5. The effects of arousal conditions and levels of difficulty on Log Integrated Absolute Error, LIAE, the index of performance. Each point is the mean score of subjects, 12, and replications, 3 (i.e.,  $n = 36$ ).

Table 3a

Summary of Analysis of Variance for LIAE; Complete Model.

SV	df1,df2	MS	F
Arousal(F)	2,22	.01	.32
Difficulty(F)	2,22	9.94	147.25***
Subjects(R)	11,216	.40	30.24***
AxD	4,44	.01	.55
AxS	22,216	.02	1.61
DxS	22,216	.06	5.17***
AxDxS	44,216	.01	.94
Replications (R)/AxDxS	216, -	.01	-

(F) = fixed variable; (R) = random variable  
<sup>\*</sup>p ≤ .05; <sup>\*\*</sup>p ≤ .01; <sup>\*\*\*</sup>p ≤ .001

Table 3b

Summary of Analyses of Variance for LIAE; Partitioned Data,  
Models Conditional on Levels of Difficulty.

SV	df1,df2	EASY		MED		DIFF	
		MS	F	MS	F	MS	F
Arousal(F)	2,22	.01	.99	.01	.63	.00	.13
Subjects(R)	11,72	.20	10.63***	.17	18.70***	.16	18.10***
AxS	22,72	.01	.48	.01	1.52	.02	1.98*
Replications (R)/AxDxS	72, -	.02	-	.01	-	.01	-

(F) = fixed variable; (R) = random variable  
<sup>\*</sup>p ≤ .05; <sup>\*\*</sup>p ≤ .01; <sup>\*\*\*</sup>p ≤ .001

indicated that processing capacity had not been exceeded. Therefore, for purposes of subsequent control activity measure analyses, the assumption was made that subjects, in general, were operating within their processing capacities. The absence of an arousal-by-difficulty interaction together with high performance levels for all subjects at all levels of difficulty relative to peak performance during training further supported this position. The resulting predictions, based upon the previously described hierarchical model, held that control activity for this second-order control system should diminish with increasing non-task stimulation.

#### Experimental Manipulations and Control Activity

To conform to the assumptions of the analyses of variance, common log transforms were applied to integrated absolute control displacement and velocity to generate LIACD and LIACV scores, respectively. As may be noted in Figures 6a, 6b, and 6c, control activity consistently decreased as levels of non-task stimulation increased. Separate analyses of variance for each activity measure are summarized in Table 4a for all data and conditional upon level of difficulty for each measure in Tables 4b, 4c, and 4d for LIACD, LIACV, and threshold velocity count, TVC, respectively. In spite of strong subject effects, the measure of average amplitude of control displacement, LIACD, was reliably affected by arousal conditions,  $F(2,22) = 4.97$ ,  $p \leq .05$ . Arousal condition effects on IACV, while not reliable, are of interest,  $F(2, 22) = 2.73$ ,  $p \leq .08$ . The overall analysis of variance, Table 4a, indicated highly



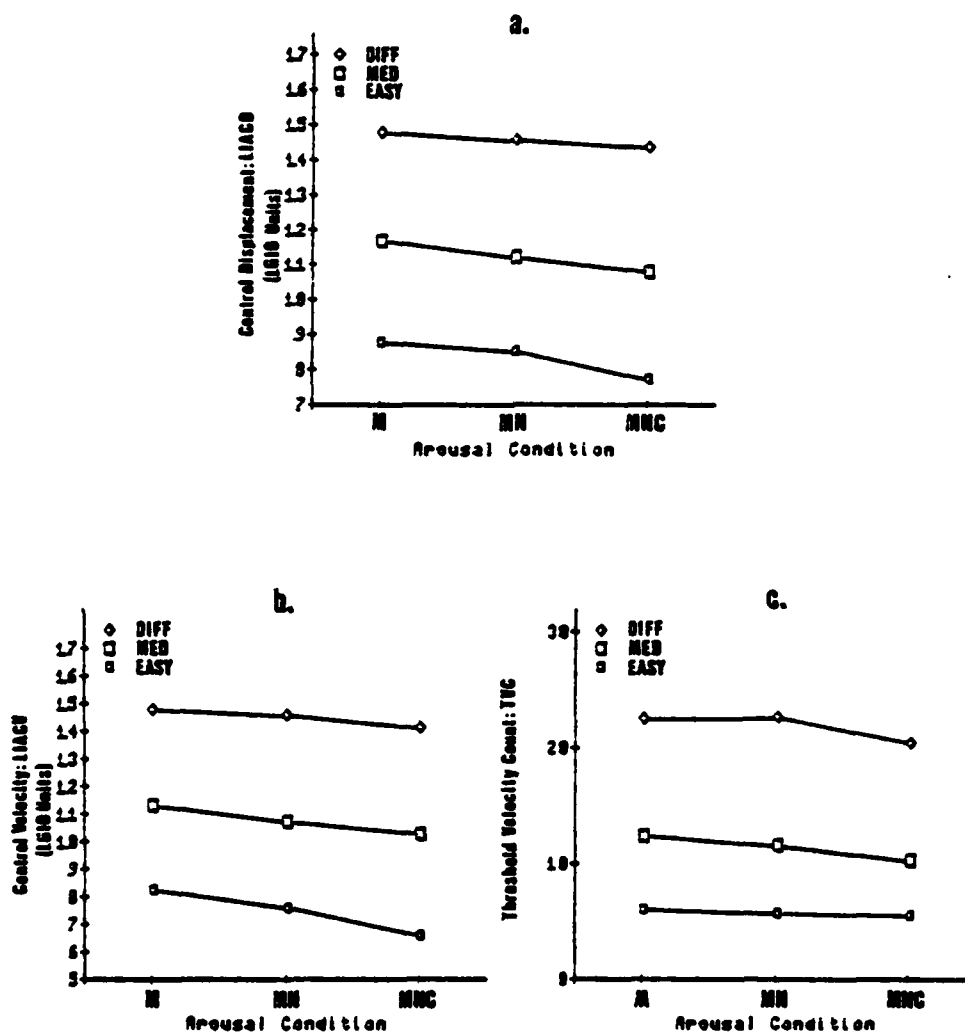


Figure 6. The effects of arousal conditions and levels of difficulty on three control activity measurement scores. a. Log Integrated Absolute Control Displacement, LIACD, is an index of average amplitude of control displacement. b. Log Integrated Absolute Control Velocity, LIACV, is an index of average velocity of control displacement. c. Threshold Velocity Count, TVC, is a discrete count of control displacements exceeding a velocity of 36 deg/sec. Each point is the mean score of subjects, 12, and replications, 3 (i.e.,  $n = 36$ ).

Table 4a

Summary of Analyses of Variance for LIACD, LIACV and TVC; Complete Models.

SV	df1, df2	LIACD		LIACV		TVC	
		MS	F	MS	F	MS	F
Arousal(F)	2, 22	.17	4.97*	.31	2.73	70.09	1.22
Difficulty(F)	2, 22	10.45	148.10***	12.01	69.30***	7100.78	44.53***
Subjects(R)	11, 216	.44	22.08***	1.53	35.58***	1843.99	61.41***
AxD	4, 44	.01	1.17	.02	.74	13.19	.58
AxS	22, 216	.03	1.75*	.11	2.62**	57.41	1.91*
DxS	22, 216	.07	3.57***	.17	4.04***	159.47	5.31***
AxDxS	44, 216	.01	.62	.03	.75	22.73	.76
Replications (R)/AxDxS	216, -	.02	-	.04	-	6486.00	-

(F) = fixed variable; (R) = random variable

\* $p \leq .05$ ; \*\* $p \leq .01$ ; \*\*\* $p \leq .001$

Table 4b  
Summary of Analyses of Variance for LIACD; Partitioned Data,  
Models Conditional on Levels of Difficulty.

SV	df1,df2	EASY		MED		DIFF	
		MS	F	MS	F	MS	F
Arousal(F)	2,22	.11	2.84	.07	6.22**	.01	1.83
Subjects(R)	11,72	.35	7.85***	.05	5.94***	.18	25.96***
AxS	22,72	.04	.88	.01	1.55	.00	1.13
Replications (R)/AxDxS	72, -	.04	-	.01	-	.01	-

(F) = fixed variable; (R) = random variable  
\* $p \leq .05$ ; \*\* $p \leq .01$ ; \*\*\* $p \leq .001$

Table 4c  
Summary of Analyses of Variance for LIACV; Partitioned Data,  
Models Conditional on Levels of Difficulty.

SV	df1,df2	EASY		MED		DIFF	
		MS	F	MS	F	MS	F
Arousal(F)	2,22	.23	1.81	.09	2.73	.03	2.07
Subjects(R)	11,72	1.17	11.67***	.48	26.46***	.22	21.73***
AxS	22,72	.13	1.27	.03	1.82*	.02	1.62
Replications (R)/AxDxS	72, -	.10	-	.02	-	.01	-

(F) = fixed variable; (R) = random variable  
\* $p \leq .05$ ; \*\* $p \leq .01$ ; \*\*\* $p \leq .001$

Table 4d  
Summary of Analyses of Variance for TVC; Partitioned Data,  
Models Conditional on Levels of Difficulty.

SV	df1,df2	EASY		MED		DIFF	
		MS	F	MS	F	MS	F
Arousal(F)	2,22	1.36	.06	39.15	.99	55.95	1.34
Subjects(R)	11,72	150.04	10.19***	1025.91	38.23***	787.00	27.21***
AxS	22,72	21.38	.62	39.68	1.48	41.79	1.45
Replications (R)/AxDxS	72, -	34.35	-	26.83	-	28.90	-

(F) = fixed variable; (R) = random variable  
\* $p \leq .05$ ; \*\* $p \leq .01$ ; \*\*\* $p \leq .001$

reliable effects of difficulty on all three activity measures and no reliable arousal by difficulty interactions.

Linear contrasts summarized in Tables 4e and 4f indicate fairly balanced reliability of arousal-condition effects for both LIACD and LIACV, respectively. Linear contrasts on TVC indicate a slightly greater impact of arousal conditions between the MN and MNC manipulations, Table 4g.

The conditional analyses of variance, Tables 4b and 4c, indicate highly reliable,  $F(2,22) = 6.22$ ,  $p \leq .01$ , and interesting,  $F(2,22) = 2.73$ ,  $p \leq .08$ , decreases in control activity with increased arousal condition stimulation at the medium level of difficulty for LIACD and LIACV, respectively. Differences among arousal condition effects failed to even approach reliability for all TVC analyses. At all levels of difficulty, for both LIACD and LIACV, arousal condition effects were never far from statistical reliability (All  $ps \leq .18$ ). While the varying pattern of reliability might seem to suggest a statistically unsubstantiated interaction between arousal and difficulty, the result is not inconsistent with loss of test sensitivity involved in the partitioning of data based on levels of difficulty. A possible explanation of the apparently more reliable effect of arousal conditions during medium level of difficulty trials can be generated consistent with the proposed conceptual framework espoused for this study.

Performance on easy trials at all levels of arousal was accompanied by a generally low level of control activity (based on both LIACD and LIACV scores). Therefore, subjects may have been approaching

Table 4e

Summary of Selected Orthogonal Linear Contrasts for  
Effects of Arousal Conditions on LIACD; Complete Model.

Contrast	df2	SS	F
MN vs. MNC	22	.1166	3.37
M vs. MN+MNC	22	.2271	6.57*

(F) = fixed variable; (R) = random variable  
\* $p \leq .05$ ; \*\* $p \leq .01$ ; \*\*\* $p \leq .001$

Table 4f

Summary of Selected Orthogonal Linear Contrasts for  
Effects of Arousal Conditions on LIACV; Complete Model.

Contrast	df2	SS	F
MN vs. MNC	22	.1978	1.76
M vs. MN+MNC	22	.4153	3.70

(F) = fixed variable; (R) = random variable  
\* $p \leq .05$ ; \*\* $p \leq .01$ ; \*\*\* $p \leq .001$

Table 4g

Summary of Selected Orthogonal Linear Contrasts for  
Effects of Arousal Conditions on TVC; Complete Model.

Contrast	df2	SS	F
MN vs. MNC	22	85.63	1.49
M vs. MN+MNC	22	54.54	.95

\* $p \leq .05$ ; \*\* $p \leq .01$ ; \*\*\* $p \leq .001$

a floor effect or lower bound of control activity consistent with the task forcing function. Thus, motor efficiency might have been approaching asymptote on easy trials, which might explain the apparently lower arousal condition effect on mean control activity. During difficult trials the subjects, on average, were likely to have been approaching their maximum task-related capacity; thus, subjects may have been approaching maximum efficiency of control activity on difficult trials for a somewhat different reason than on easy. On medium difficulty trials subjects were less likely to have been limited by a floor effect on control activity or by limited processing capacity and thus, could generate the results obtained.

The results suggest that, within processing capacity, at or near optimal levels of performance, increased arousal results in a reduction of control activity in second-order control systems regardless of the level of task complexity as operationally defined in this experiment. That arousal generally increased with increasing non-task stimulation (the arousal manipulations applied) and with increasing task stimulation (the levels of difficulty) was supported by traditional measures of arousal.

That control activity measures were sensitive to level of stimulation manipulations was supported by the data. That at least one of these measures (LIACD) was more sensitive to changes in non-task levels of stimulation than was a traditional and representative measure of performance (LIAE) was also supported. The consistency of control activity mean trends across increasing levels of stimulation regardless

of level of task complexity suggests that the progress toward motor control efficiency with skill development (supported in other cited studies involving second-order compensatory tracking systems) is paralleled by the effects of increasing non-task stimulation prior to decremental performance effects of such stimulation.

#### Additional Descriptive Analyses

Within the limited scope of this study, it was considered of interest to perform selected post hoc descriptive analyses to further clarify the relationships among the measures and manipulations employed. Tables 5a and 5b summarize two such analyses, both generating Kendal Tau rank-order correlation matrices (Bradley, 1968). Table 5a addresses the question of whether the dependent measures were sensitive to arousal condition manipulations. Arousal conditions (M, MN, and MNC) were assigned ranks (1, 2, and 3, respectively) based on increasing levels of stimulation (non-task load) as operationally defined; dependent measures were assigned ranks based upon means of appropriately collapsed data. Table 5b addresses the question of whether the dependent measures were sensitive to the level of difficulty manipulations. Levels easy, medium, and difficult were assigned ranks 1, 2, and 3, respectively, corresponding to increasing task difficulty (task stimulation).

In Table 5a, TCS (Thayer Checklist Scores) and all three control activity measure ranked-means generated reliable ( $p \leq .05$ ) Tau coefficients relative to arousal conditions as ranked. LIACD generated the most reliable ( $p \leq .001$ ) Tau coefficient,  $-.46$ . Other relationships of

Table 5a

Summary Matrix of Kendall Tau Rank-Order Correlation Coefficients  
 Relating Applicable Measurement Means to Rank-Ordered  
 Arousal Conditions (Assigned Ranks: M = 1, MN = 2, and MMC = 3)

	Arousal	TCS	LIAE	LIACD	LIACV
Arousal	-				
TCS	.27*	-			
LIAE	-.08	.26*	-		
LIACD	-.46***	-.26*	.00	-	
LIACV	-.26*	-.07	-.03	.78***	-
TVC	-.31*	-.27*	-.07	.56***	.67***

\* $p \leq .05$ ; \*\* $p \leq .01$ ; \*\*\* $p \leq .001$

All: N = 36

Table 5b

Summary Matrix of Kendall Tau Rank-Order Correlation Coefficients  
 Relating Applicable Measurement Means to Rank-Ordered  
 Levels of Difficulty (Assigned Ranks: EAST = 1, MED = 2, and DIFF = 3)

	Difficulty	SR(ALS)	LIAE	LIACD	LIACV
Difficulty	-				
SR(ALS)	+.65	-			
LIAE	1.00	+.62	-		
LIACD	1.00	+.62	1.00	-	
LIACV	.94	+.71	.94	.94	-
TVC	.94	+.71	.94	.94	1.00

All:  $p \leq .001$

Excludes S7 & S9, i.e., n = 30; otherwise, n = 36.



interest are present in the matrix, but are left to the reader to examine. The matrix does, however, suggest an equivalent or greater sensitivity of control activity measures to changing levels of stimulation relative to a traditional measure of arousal.

In Table 5b, when ranks were assigned relative to levels of difficulty, all measures generated highly reliable ( $p \leq .001$ ) Tau coefficients. Of particular interest is the fact that the computed coefficients for activity measures relative to levels of difficulty and performance were higher ( $\text{Tau} \leq .94$ ) than for SR(ALS) relative to ranked difficulty ( $\text{Tau} = .65$ ) and performance ( $\text{Tau} = .12$ ). Also of interest is the reasonably high Tau coefficient relating ranked SR(ALS) means with ranked levels of task difficulty. One might argue that this matrix is of little interest because level-of-difficulty is a direct task-related manipulation and performance and control activity measures are task-dependent measures, while SR(ALS) is not so congruent with the task; such congruency is suggested to support the proposed value of control activity measures in relating arousal and performance in tasks involving manual control.

In an attempt to further examine the relationships between LIAE and the three control activity measures, a separate analysis of variance test for linearity was conducted for each activity measure for overall data and at each level of task difficulty with LIAE as the criterion variable. An abbreviated summary of these results are presented in Table 6. The table presents: (a) the ANOVAR level of significance of the linear component; (b)  $\text{ETA}^2$  an estimate of the total

Table 6

Summary of Selected Results of Analyses of Variance Tests for Linearity  
Relating LIAE, as the Dependent Variable, to the Control Activity Measures  
Based on Complete and Partitioned Data.

Source	$p > (F)$ (ANOVA Significance Linear Component)	$\eta^2$	$r^2$	( $r_p$ )
LIACD	***	.9305	.4975	+
LIACD(EASY)	***	.9519	.1969	+
LIACD(MED)	.066	.9298	.0203	-
LIACD(DIFF)	.325	.9144	.0204	-
LIACV	***	.9322	.2240	+
LIACV(EASY)	.97	.8796	.0000	+
LIACV(MED)	.21	.9482	.0215	-
LIACV(DIFF)	*	.9848	.2026	-
TVC	***	.2817	.1366	+
TVC(EASY)	.68	.3544	.0014	+
TVC(MED)	.73	.4154	.0009	-
TVC(DIFF)	***	.3824	.2203	-

\*  $p \leq .05$ ; \*\*  $p \leq .01$ ; \*\*\*  $p \leq .001$

variance in LIAE, accounted for by the specified control activity measure; (c)  $\underline{r}^2$  an estimate of the linear variance in LIAE accounted for by the specified control activity measure; and (d) the sign of the  $\underline{r}$  associated with  $\underline{r}^2$ .  $\text{ETA}^2$  minus  $\underline{r}^2$  provides an estimate of the non-linear variance accounted for by the activity measure specified.

As may be noted and of particular interest is the relatively high non-linear variance accounted for by the measures (especially LIACD and LIACV). Since for each measure of control activity there is a consistent pattern of increasingly negative  $\underline{r}$ s as a function of increasing task complexity (see Table 6) and a fairly uniform curvilinear trend in overall data scatterplots (LIAE plotted as a function of each control activity measure; plots not presented with this report), continued curvilinear regression analyses might prove to be informative. Such analyses have not been conducted to date for practical reasons.

Finally, a single multiple regression of control activity measures with LIAE as the dependent measure was computed for all data. The results, summarized in Table 7, indicate a strong relationship between the control activity measures employed and LIAE. All estimated parameters (intercept and slopes) achieved statistical reliability (all  $t$ s (320)  $\geq |3.39|$ ; all  $p$ s  $\leq .001$ ) and together generate a highly reliable multiple regression  $\underline{R}^2 = .55$ ,  $F(3,320) = 131.55$ ,  $p \leq .0001$ . While much of this relationship seems to depend upon the effects of levels of difficulty on obtained scores, there seems little risk in asserting a clear functional relationship between control activity and performance. A clearer discrimination of how this relationship can be brought to

Table 7  
Summary of a Multiple Regression of Control Activity Measures  
on LIAE, the Criterion Variable.

Source	df	MS	F	p > (F)	
LIACD	1	14.71	355.56	.0001	
LIACV	1	1.14	27.58	.0001	R <sup>2</sup> = .55
TVC	1	.48	11.51	.0008	
Error	320	.04	-	-	

Parameter	Estimate	T for H0: Parameter = 0	p > (T)	STD Error of Estimate
Intercept	.247	5.53	.0001	.045
LIACD	.992	15.31	.0001	.065
LIACV	-4.07	-6.12	.0001	.066
TVC	.005	3.39	.0008	.002

bear to aid in the understanding of arousal effects on performance is left to future investigations.

### Conclusion

This study examined the relationships between control activity, performance and arousal. Experimental non-task load (arousal) manipulations failed to generate significant performance effects, but did reliably affect at least one of three control-activity measures employed, namely, integrated absolute control displacement, IACD. The results offer support for a progression hypothesis. This hypothesis asserts that trends in control activity demonstrated at any given level of performance during skill development are paralleled by trends exhibited as arousal or, at least, non-task stimulation increases. Since performance failed to demonstrate a decrement, a proposed set of related regression hypotheses could not be tested.

This study, as originally planned, was to have employed an arousal manipulation specifically designed to affect the Air Force ROTC cadets who acted as subjects for this study. The manipulation would have involved a (spurious) serious threat to each subject's future assignment to pilot training based on performance; certain policy-related Air Force requirements precluded the administration of this proposed arousal condition. It is suggested that such a manipulation might be required to generate a sufficiently large non-task load to effect a performance decrement without reverting to a task-load or secondary task manipulation to force a decrement.

While all subjects in this study generated acceptable performance levels, additional practice would have had the advantageous effect of minimizing intra-subject performance variability, especially in the

mission-segment mode of operation used for the experimental manipulations. Further, while a majority of subjects generally demonstrated a reduction with practice in control activity at any given level of performance, this study allowed for no statistical confirmation of this trend due to the relatively short training period dictated by practical considerations. Taken together, the above suggest that a replication of this study should extend the training period available and should explore other, more effective, arousal manipulations consistent with the ethical treatment of human subjects. Certain non-laboratory, operational environments may provide non-manipulative frameworks for the design for such experimentation.

If trends in simple control activity measures can be more definitively related to the effects of non-task load (total environmental stimulation) on performance, a potential exists for identifying more adequate selection and screening instruments for occupations involving critical manual control operations. Further, since control activity parameters are "part and parcel" with task execution, machine system-augmented performance might be realized through the application of behavioral feedback techniques. Finally, if arousal and learning effects can be more meaningfully related through the development or rejection of the proposed hierarchical model, the contribution to our knowledge of man, the controller, may be considerable.

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## Appendix A

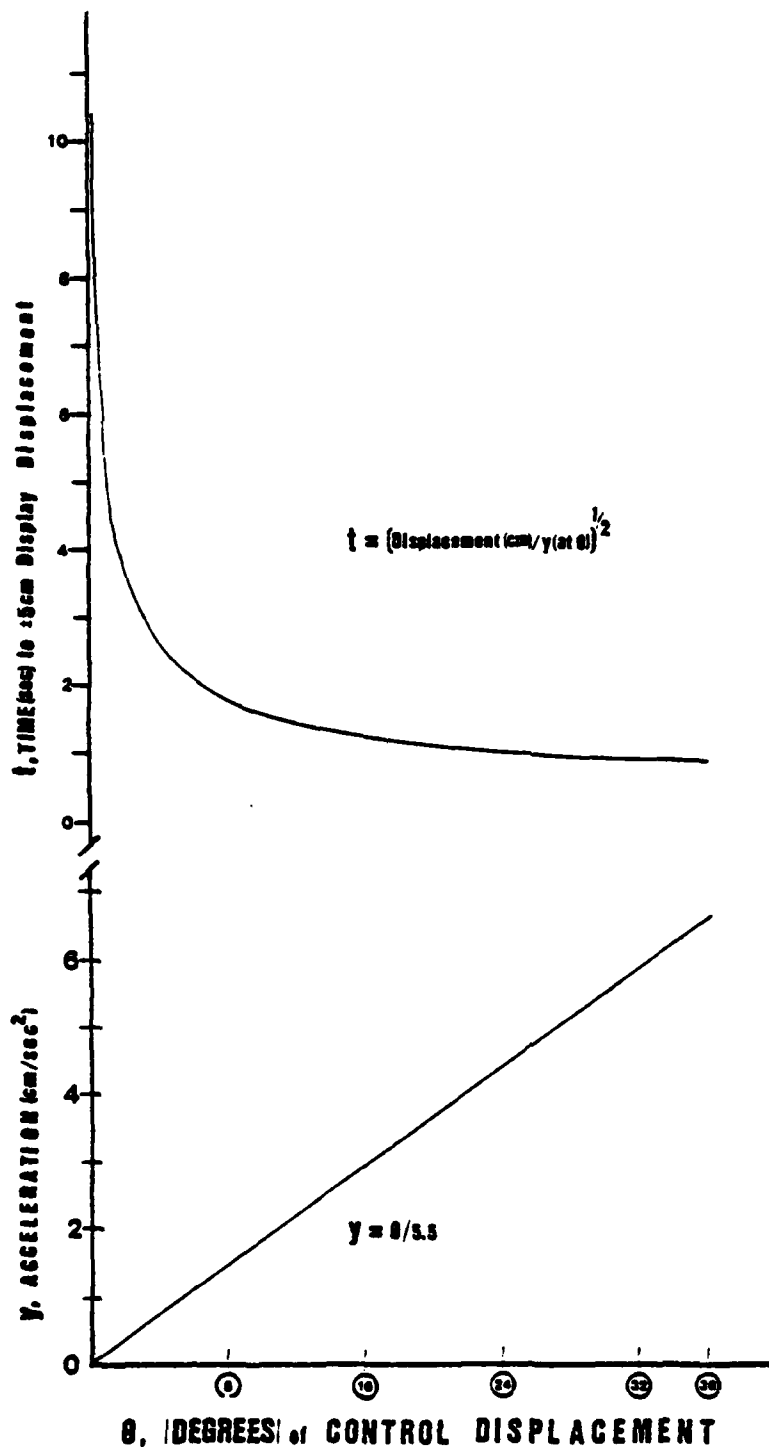
### Experimental Apparatus and Basic Information Flow

Appendix Figure 7 presents the control dynamics of the system without regard for the .6-second time delay prior to the first integrator.

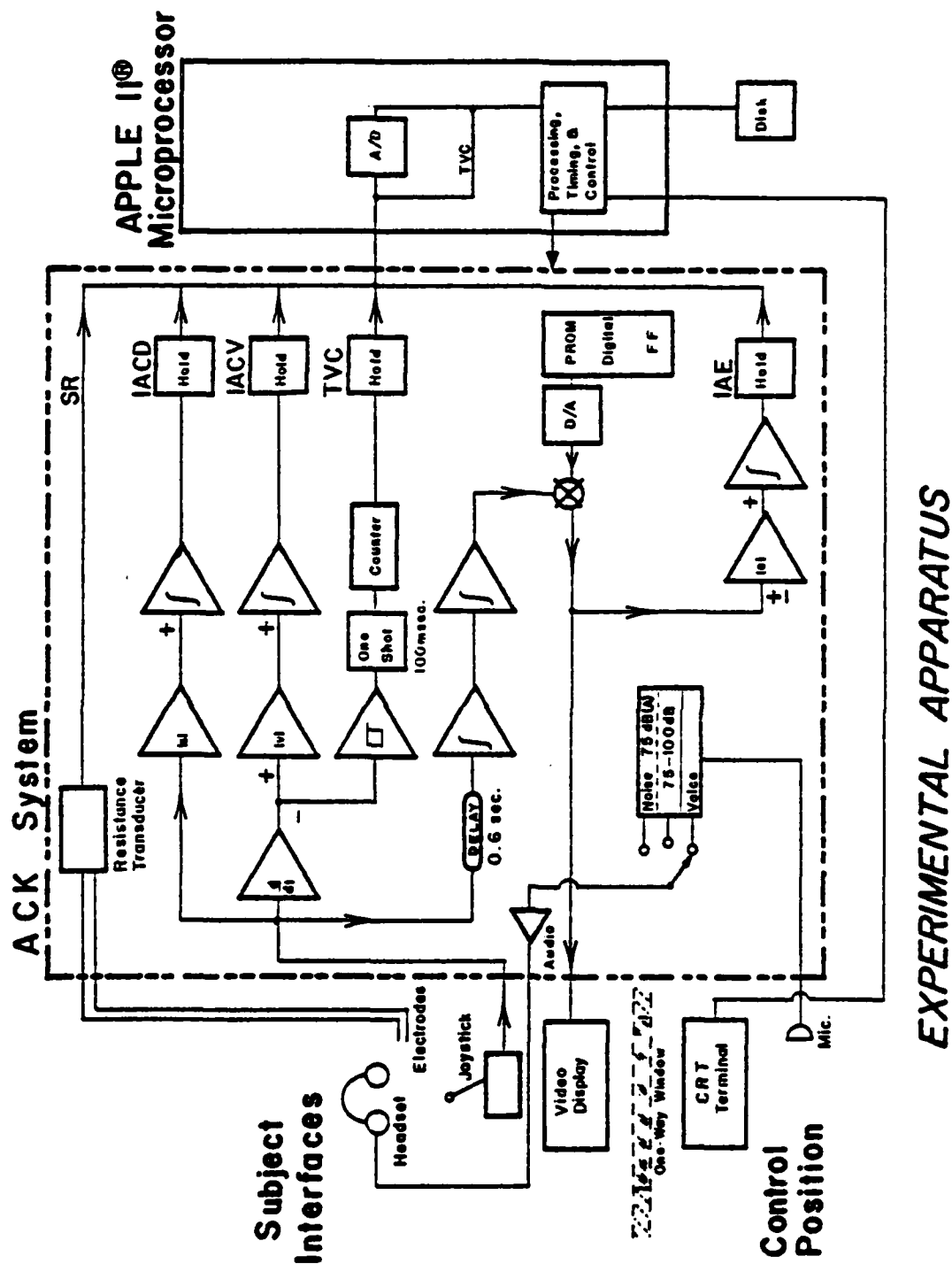
Appendix Figure 8 illustrates the functional relationships of the various components involved in this experiment. Formal electronics schematics are available upon request.

Appendix Figure 9 illustrates the forcing function (FF), a digital version of which was stored in PROM within ACK, and notes the three start points used in this experiment.

Appendix Figures 10a and 10b provide illustrations of the basic FF-to-time relationships involved in the single-trial and mission segment modes of operation, respectively.

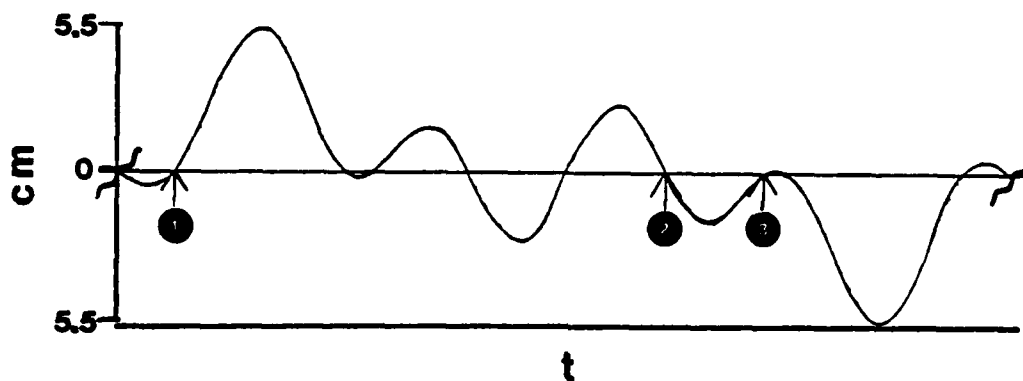


Appendix Figure 7. Second-order control dynamics without regard for the .6-second time delay incorporated for this tracking task.

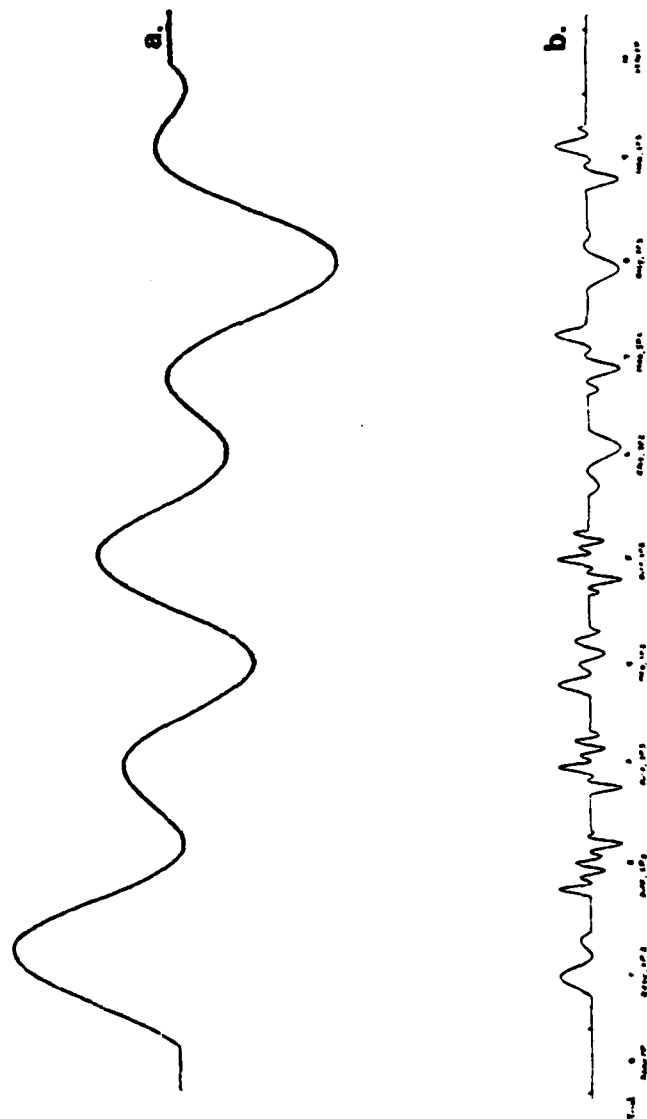


Appendix Figure 8. Experimental apparatus and information flow.





Appendix Figure 9. Illustration of the forcing function,  $FF$ .  
Selected start points are annotated.



**Appendix Figure 10.** Single-trial (a.) and mission segment (b.) modes of operation. The above examples are of the: (a.) single-trial mode, start point 1, Level of difficulty: Difficult; and (b.) the mission segment mode, experimental (Day 3), Subject 1. Note that each trial begins at zero-crossing.

## Appendix B

### Discussion of Measures and Arousal Manipulations

Appendix A, Figure 10, illustrates the timing of events for the two basic modes of operations in this experiment. The two modes illustrated are the single-trial mode and the mission segment mode. A trial was the measurement period used throughout the experiment with a duration of 24.576 seconds. Both single trials and mission segments began with a five-second visual countdown signalled at one-second intervals by a flashing green light. A steady green light corresponded to a trial or measurement period; a steady red light corresponded to a period of tracking while no measures were taken; and lights off corresponded to no action required by the subject.

Mission segments consisted of a countdown followed by 11 trials (numbered 0-10) each separated by a 12.3-second, red-light period. The first and last trials in the sequence and the red-light periods involved no forcing function and provided skin resistance and previous level-of-difficulty "settling" periods for the subject. A mission segment, then, required approximately 6 minutes and 58 seconds of continuous tracking.

One measure of overall tracking performance, three of joystick movement activity and two of arousal/activation, were taken. All but the second arousal/activation measure detailed below provided a single score per subject per trial.

### Overall Tracking Performance

Integrated Absolute Error, IAE, derived as illustrated in Appendix A, Figure 8, provided an index of the average absolute deviation from zero error as presented at the subject's display during each trial. Levels of difficulty of the forcing function were selected such that a talented and practiced tracker could maintain approximately 80%, 40%, and 20% of the error generated by the difficult, medium, and easy FFs (as measured without control dynamics connected), respectively. For the experiment, the obtained corresponding (approximate) percentages were: Best tracker: 78%, 39%, and 17%; Worst tracker: 231%, 91%, and 48%; and Average tracker: 120%, 57%, and 27%. The scores stored were arbitrarily scaled to represent a percentage of the maximum error the tracking system could generate with maximum stick deflection with no forcing function over a period of measurement, 24.576 seconds.

Subject instructions reflected the nature of this overall performance measure and verbal feedback was restricted to IAE scores throughout training.

### Joystick Movement Activity

At no time during the experiment were subjects informed that the following measures were being taken.

Integrated absolute control displacement. This measure, IACD, provided an index of the average absolute amplitude displacement of the joystick from the neutral or centered upright position over the period of measurement. Assuming a tracking system with incremental energy cost per unit displacement per unit time, IACD would provide an index

of efficiency of control displacement activity. Given equal IAE scores, a lower IACD score would reflect more efficient average control movement behavior. Scaled in the same way as IAE (maximum deflection, no FF, over the period of measurement), IACD was derived as illustrated in Appendix A, Figure 8. Obermeyer et al. (1961) noted that low IACD was characteristic of skilled performance with a compensatory-acceleration display-control system. Their work comparing various display-dynamics combinations underlines the need to choose system-specific control movement activity measures for applications such as this one.

Integrated absolute control velocity. Derived as illustrated in Appendix A, Figure 8, IACV provided an index of average "velocity" or "smoothness" of control stick-movement activity over the period of measurement. The IACV measure captures a related but distinct aspect of control activity when compared with IACD. A smooth, efficient (in system terms) and accurate tracker would have low IACV, IACD, and IAE scores, respectively. If the tracker applies a dither strategy and remains accurate at the tracking task, one would expect high IACV scores (reflecting less smooth, high-velocity motor activity) but low IACD and IAE scores. Another illustration of how IACV captures a different dimension of movement activity is a pattern like high IACD, low IACV and high IAE. Such a pattern would indicate slow, high-amplitude control movements with poor correspondence to FF requirements, in other words, poor and under-controlling tracking behavior.

IACV scores were scaled such that they represented degrees/second of control displacement with a maximum average displacement measurable

of 100 deg/sec over the measurement period. System gain was set to be just insensitive to high muscle-tension-induced tremor.

Threshold velocity count. Derived as illustrated in Appendix A, Figure 8, TVC simply provided a count of discrete control movements exceeding a threshold velocity of 36 deg/sec. This threshold corresponds to the displacement velocity required to go from stop-to-stop across center in two seconds. Extreme TVC scores in conjunction with moderate IACV scores would indicate sporadic dither episodes within a measurement period. Low to moderate TVC scores and high IACV scores would imply a "bang-bang" control strategy, involving high-amplitude, high-velocity control movements.

#### Arousal/Activation

Average skin resistance. Interpreted to reflect changes in activation per changes in sweat gland activity mediated by the sympathetic nervous system (generally accepted to reflect the "preparation for action and energy expenditure" branch of the central nervous system), ASR measures were used to provide an index of arousal/activation during each trial (thus, between the three levels of difficulty within mission segments).

The locally designed and manufactured ACK subsystem provided a reading of absolute skin resistance twice per second for analog-to-digital conversion. The resulting 49 samples per trial were stored as raw data and averaged for storage and display as trial scores (ASR). The system provided readings from 0 to 600k ohms. As with all of the

tracking scores above, each mission segment provided 9 trial scores, 3 at each level of difficulty.

Thayer Activation/Deactivation Adjective Checklist. The AD ACL, first published by Thayer in 1967, is a pencil-and-paper test which subjects filled out after each mission segment, thus after each arousal condition manipulation. Since, for each subject, the three mission segments were identical and since the sequence of arousal conditions was counterbalanced between subjects, the scores thus derived may be considered primary indices of arousal condition effects.

Notes on stimulus manipulations--arousal conditions. Three arousal conditions were employed in this experiment. The manipulations involved both symbolic and physical stimulus changes. The "M" condition, with the steady 75 dB(A) noise, was considered a base-level condition, equivalent to the physical auditory stimulation presented throughout training. The second condition (MN) introduced a 75dB(A) to 100 dB(A) oscillating noise (15 cpm triangle wave presentation over head-set). Teichner et al. (1963) recommended the use of a periodic duty cycle to minimize habituation artifacts. The effective average dB(A) levels were well within levels prescribed for subject well-being (Deatherage, 1972; Poulton, 1972). The resulting increased physical stimulation may be inferred to increase arousal, but was measured to confirm this result.

The third manipulation involved the introduction of the oscillating noise and the introduction of two symbolic stimuli. Instructions informed the subject that his performance scores on this mission seg-

ment (MNC arousal condition) were to be entered into competition with his peers for a \$50 bonus to go to the best performer. In addition, the subject was informed that his scores on this run would be posted for inspection by his peers at the Air Force Reserve Officer Training detachment. This second symbolic stimulus is regarded as a threat to the tracker's self-esteem. Once again the addition of threat and competition might be inferred to combine with the auditory noise manipulation to increase level of stimulation; in this experiment, "increased arousal" is operationally verified and measured as relayed above.



## Appendix C

### Subject Forms

Appendix Figure 11 presents a sample of the Volunteer Sheet/  
Schedule which subjects filled out prior to experimental participation.

Appendix Figures 12a and 12b illustrate the instructions and  
checklist, respectively, which make up the Thayer Activation/Deactivation  
Adjective Check List.

VOLUNTEER SHEET/SCHEDULE

Assigned# \_\_\_\_\_

1. Cadet Name: \_\_\_\_\_  

Last
First
Mi
Rank
2. a. Age \_\_\_\_\_, \_\_\_\_\_ b. Academic status: FR SO JR SR  

years
Mos

 c. Academic Major/Minor: \_\_\_\_\_/\_\_\_\_\_
3. Preferred Hand: RT LT
4. Flying Experience: Yes No. If yes, specify: \_\_\_\_\_, \_\_\_\_\_  

Hrs
type
5. I will meet with Capt. Acosta for:  
 Training Session-Day 1 on \_\_\_\_\_, \_\_\_\_\_ at \_\_\_\_\_ AM PM  
 Training Session-Day 2 on \_\_\_\_\_, \_\_\_\_\_ at \_\_\_\_\_ AM PM  
 Performance Session-Day 3 on \_\_\_\_\_, \_\_\_\_\_ at \_\_\_\_\_ AM PM  

day
date
time
6. My phone number is \_\_\_\_\_. I will call Capt. Acosta at  
 522-1987 prior to 8 AM as soon as I am aware of any problem.

SIGNED \_\_\_\_\_

POST-EXPERIMENTAL COMMENTS:

SIGNED \_\_\_\_\_

AD-A133 921

CONTROL DEVICE MANIPULATIVE BEHAVIOR AROUSAL AND  
PERFORMANCE DURING A COM..(U) AIR FORCE INST OF TECH  
WRIGHT-PATTERSON AFB OH H M ACOSTA DEC 80  
AFIT/CI/NR-80-83T

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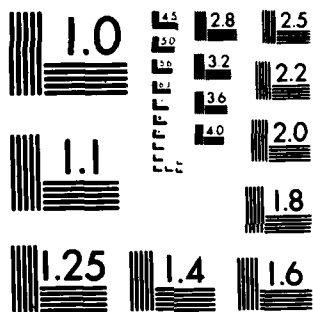
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DATE

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11 83

DTIC



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS 1963-A

